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ECONOMICAL RESIDENTIAL PRESSURE
SEWER SYSTEM WITH NO EFFLUENT

SIECO, INCORPORATED

PREPARED FOR
MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY

DECEMBER 1975

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ECONOMICAL RESIDENTIAL PRESSURE SEWER SYSTEM WITH NO EFFLUENT



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ECONOMICAL RESIDENTIAL PRESSURE SEWER SYSTEM
WITH NO EFFLUENT

by

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The technology described in this report represents one of the first attempts to provide improved wastewater management for rural populations in an economical manner while incorporating concepts of recycling valuable nutrients to the land with concomitant elimination of additional pollutant loads on surface water resources.

Louis W. Lefke
Acting Director
Municipal Environmental
Research Laboratory

ABSTRACT

An economical pressure sewer system with no polluting effluent was designed, constructed, and monitored for effectiveness. The elimination of groundwater infiltration and restrictive elevation tolerances associated with a conventional gravity sewer system enabled this type of sewer system to be installed and to function economically. The treatment process, aerobic and anaerobic lagoon storage with subsequent irrigation of the effluent, yielded no more than normal volume of runoff.

Operational problems with the pressure system resulted from inefficient home grinder-pump units. These problems were greatly reduced when commercially manufactured home units became available. The treatment process functioned as anticipated. Because of the new sewer system, summer homes become year around residences and new home construction exceeded expectations. As a result, the initial irrigation area proved inadequate for handling the actual flows and additional irrigation area was made available at a later date.

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SECTION I

CONCLUSIONS

1. It is possible to provide a sewage treatment facility meeting a zero-discharge standard for small communities.
2. Domestic sewage nitrogen and phosphate can largely be converted to vegetation at a reasonable cost for small communities.
3. Ground raw sewage and septic tank effluent can be treated by a combined anaerobic and aerobic lagoon without objectionable odors.
4. Ground raw sewage caused some additional operation and maintenance problems due to the nature of the solids.
5. Groundwater infiltration into sewer lines is eliminated with the use of the pressure system.
6. A pressure sewage system can be cheaper to install than a conventional gravity system in areas of rough topography.
7. Operational expenses of a pressure sewage system are higher than those associated with a gravity system.
8. The home owner should be educated in the proper operation and maintenance of his home unit.
9. No male-threaded PVC pipe fittings should be used on any home unit installations.
10. Any check valves used in the home units should have a gate that, when closed, is at an oblique angle from the perpendicular alignment of the centerline of the flow in the pipe in order to use the gravitational advantage. A free turning valve gate that reseats itself after each operation proved to be more reliable and required less maintenance than one with a fixed gate.
11. Mechanical seals should be used in all possible applications of infield fabrication operations to prevent leakage due to high groundwater conditions during all or part of the year.

12. A fused electrical disconnect should be located next to any external controls of the home unit for use by the serviceman. Any contractor installing such a system for existing residences should have a flat rate for each utility service damaged during installation.

SECTION II

RECOMMENDATIONS

1. Future pressure sewer installations should strongly consider pumping only septic tank effluent.
2. A program should be instituted to determine long-term maintenance information on the effects of the ground paper products on pressure sewer lines and treatment facilities. It is only through such information that a proper cost comparison between grinder-pump installations and septic tank effluent pumping installations can be made.
3. The efficiency and dependability of any pressure switches installed to prevent excessive pressures must be established before their use is specified.

SECTION III

INTRODUCTION

Grandview Lake, located about 10 miles southwest of Columbus, Indiana, is a manmade lake with approximately 400 acres of water surface, and is shown in Figure 1. (See glossary for metric conversions from English units used throughout this text).

The lake is located in a rural section of Bartholomew County that is not productive farm land. The soil in the area is predominately clay and, therefore, provides poor drainage for crops. Scattered areas with exposed rock surfaces further reduce the agricultural value of the land. These characteristics that tend to keep land prices low also attract land developers. Such was the case at Grandview Lake, and a recreational and residential development was started.

As the Grandview Lake area developed during the last twenty years, the pollution problems inherently associated with a growing population began to become evident to the residents. These problems were aggravated by the lake developer's economic problems.

As the number of residences at Grandview Lake had grown, so had the size of the lake. Financial difficulties had hampered the completion of the lake's dam by the original developer. In fact, some lot owners had built septic systems on the land between their dwellings and what they anticipated as being the final lake shoreline. However, in 1960, additional funds were invested in the development and the dam was completed. When the water began to rise behind the completed dam, it began to cover some of the septic tank absorption fields installed by the early residents. Some of these installations were abandoned for new facilities on higher ground. Some continued to be used due to the ignorance of lot owners who had acquired property and were unaware of where their septic system was located. Still others were used out of indifference.

By 1967, residents of the lakeside community were becoming increasingly aware of the results of septic tank effluent failing to be absorbed into the soil. Not only were some septic systems emptying directly into the lake but the flows from many of the newer septic tanks were causing odorous wet spots in the lawns and eventually flowing into the lake. Algae growth was increasing rapidly in the fertilized lake water, small coves around the lake had a septic odor, beaches were becoming fouled, and some areas of the lake had soap suds lining the shore. Also, a rural water system had been installed (November 1969 thru May 1970) around the lake, and this was helping to attract

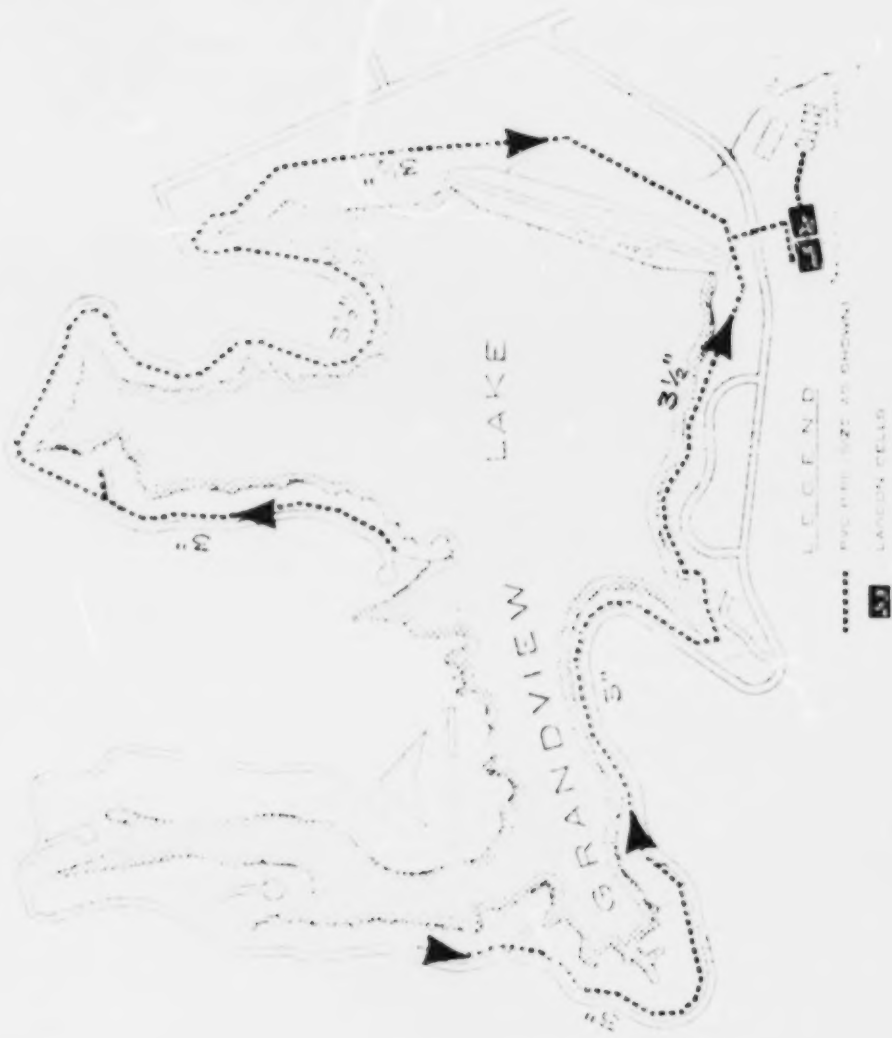


FIGURE 1. GRANDVIEW LAKE SEWAGE RESEARCH AND DEMONSTRATION PROJECT SYSTEM LAYOUT

more prospective homeowners and their sewage disposal problems.

The sewage problem could not be ignored if the lake was to continue to be a desirable center of the community life.

Individuals had attempted to solve their own sewage problems by installing various sewage disposal systems, but it was evident that a community system was needed. Investigation into the feasibility of installing a conventional gravity sewer system and treatment plant proved to be prohibitively expensive (\$10,000 per existing house), and this approach was abandoned.

The possibility of solving the sewage problem around the lake by installing a pressure sewage system was first formally proposed by SIECO, Inc. in July of 1968.

Although sewage force mains had been utilized by communities for many years, the concept of individual pumping units located at each residence was definitely an experimental proposition. A prior attempt in Kentucky had proven to be a failure. However, investigation into the Kentucky project failed to reveal the true complexity of the proposed type of system. The engineer anticipated that, by properly educating the population that would be using the system, many of the problems on the Kentucky project could be avoided. Also, the possibility of Federal research funds helped make the project economically feasible.

SECTION IV

HOME UNIT PRODUCTION PROBLEMS

Normal conditions expected when bidding a construction job did not materialize when the Grandview Lake project was advertised for bids. Most contractors originally refused to bid on the project because it was something "new and different." Those who did bid were unreasonably high. Eventually, a reasonable bid for installing the system and treatment plant was received and accepted by the owner. However, the heart of the pressure system, the individual home units, was rejected by all bidders as "too complicated."

The engineer's original concept of the home unit to be used on the project was a completely-fabricated three compartment steel tank, light enough to be easily lifted into place by a backhoe. In an effort to keep installation costs down, it was anticipated that the home unit fabricator would deliver several units at a time to the job site. The contractor could then install the units at his own pace without paying for a special piece of equipment for lifting the unit into place.

However, when the fabrication of the home units was rejected by the bidder, an alternate solution was sought to using a fabricated steel tank. The use of a molded plastic or a fiber-reinforced plastic (FRP) tank was eliminated due to the excessive mold or set-up cost associated with any initial production using those materials. A local concrete vault manufacturer did express an interest in casting the units out of concrete.

Being the only bidder willing to produce the unit housing at a reasonable cost (\$125.00/unit), the vault manufacturer was awarded the contract. He also was awarded the assembly operation, subsequently awarded to a sub-contractor, so that a totally "packaged" unit, as shown in Figure 2, would be delivered to the site.

Production problems during casting forced the vault manufacturer to increase the wall thickness of the unit. This added to the weight of the casting, but did enable the casting mold to be removed without cracking the casting. It also provided adequate room within interior partitions in the mold for the concrete to be poured without having voids in the finished casting. The casting operation still required considerably more labor than originally anticipated by the manufacturer due to the required use of vibrators to help move the concrete into the interior partitions.

Several months were spent eliminating problems with the mold. When actual production began, the manufacturer could only produce five units per week. It took five months to produce the 58 units for the project.

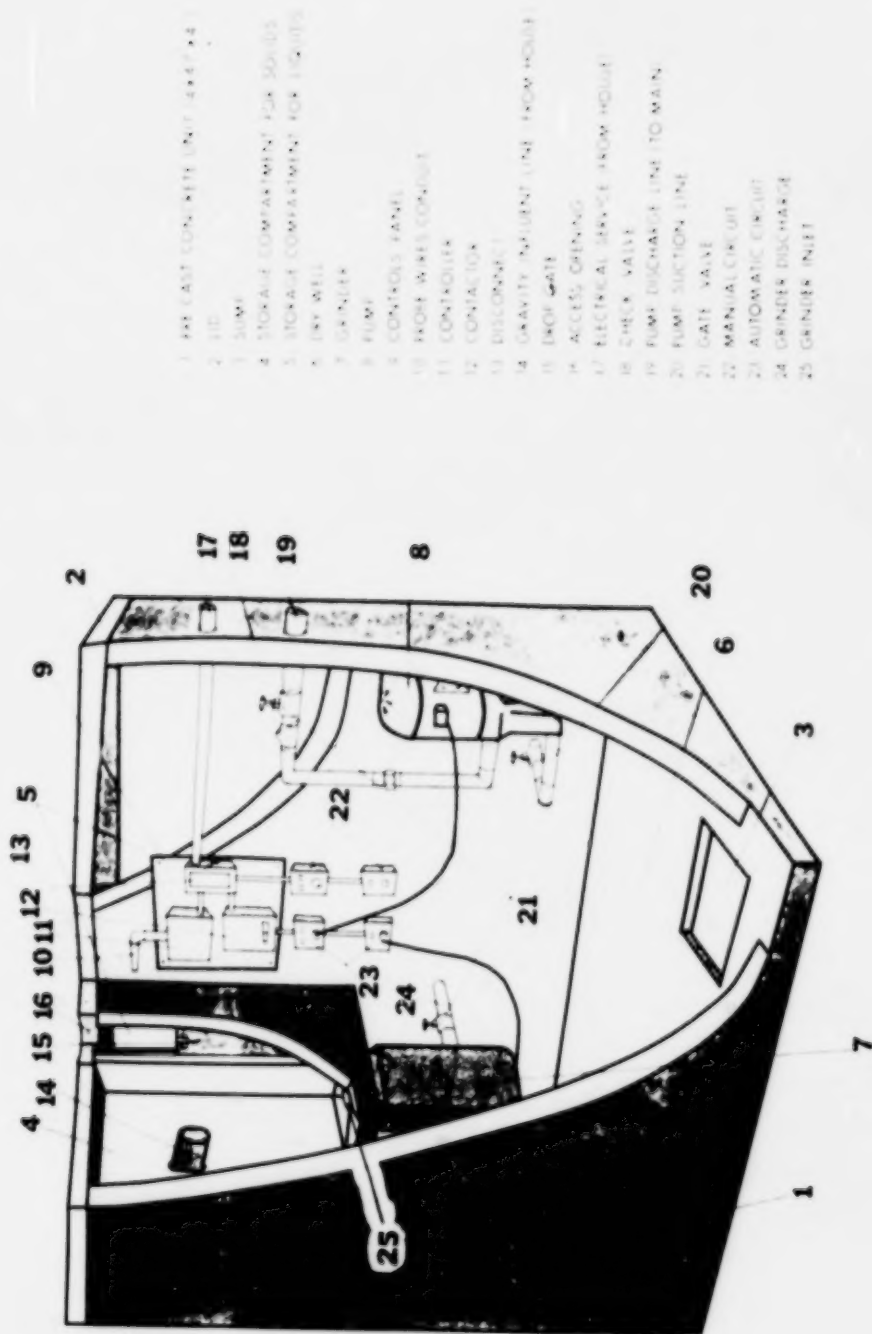


FIGURE 2. LOCALLY MANUFACTURED GRIND-PUMP UNIT

While the casting manufacturer was having his problems, the contractor doing the assembly work was also experiencing problems. Problems resulted primarily from attaching equipment, especially the garbage grinder, to the concrete casting. The unit developed leaks between the wet well and the dry well. These problems were eliminated by having threaded anchor plates cast into the concrete. A quick-setting hydraulic cement was used to secure all pipes where they passed through the walls of the casting.

A considerable amount of time was lost due to logistic problems in obtaining parts. Plastic pipe had been specified by the engineer because of its low cost, corrosion-resistance and ease of installation. The contractor found that local material supply houses did not carry the specified thickness of plastic pipe and had problems getting both the pipe and the required fittings. After each unit was completed, the fabricator tested it under the engineer's supervision. In these tests a problem was discovered during the grinding cycle of the operation. The garbage grinder was using twice the amperage indicated by the manufacturer. Correspondence with the manufacturer failed to produce a satisfactory explanation. By closely monitoring the water level above the grinder's cutting blades and the amperage being used, it was discovered that a liquid head over 8.25 inches above the cutting blades resulted in the excessive amperage. The unit was actually pumping the liquid in addition to grinding.

The normal operation of a garbage grinder consists of water and garbage being poured into the grinding chamber without building up a significant head. This accounted for the manufacturer being unaware of the situation. When conditions are such in a household garbage grinder installation, the duration of excessive power drain is usually short enough that the thermal overload on the grinder is not activated. Any such overloading that results in the thermal overload stopping the grinder would probably be blamed on "something stuck in the grinder."

The problem, overloading due to the height of the liquid level above the grinder, was solved by adjusting the liquid level controls in the unit so that the head did not exceed 8.25 inches above the cutter blades. However, this meant the storage capacity in the unit was reduced, thus requiring more operating cycles during the usage period.

In the event of a pump malfunction, it was possible for the electrical liquid-level control conduit to become submerged. It was therefore necessary to seal the wires inside of the conduit. Waterproof putty, aquarium sealer, and a petroleum base mastic cement proved ineffective in stopping the water. Eventually, a quick-setting hydraulic cement was used to solve the problem.

Piping within the units was done with Class SDR 21 PVC pipe. An immediate discovery was that no male-threaded PVC fittings could be used regardless of the wall thickness (Class 120 is the minimum acceptable by the engineer in other instances). Metal nipples screwed into threaded female PVC fittings with a solvent-weld female connection to the piping was the only type of threaded connection that did not break under stress during the operation of the pumps.

In one instance, a section of pipe connected to the discharge of a positive-displacement pump withstood an estimated pressure of 105 psi and the concomitant increase in temperature due to a closed gate valve. Although the pipe expanded to almost twice its original diameter, neither the fitting, pipe, nor weld broke. The pump failed, however.

Schedule 40 PVC pipe was used in the units after it was discovered that maintenance personnel and curious home owners used the pipes to stand on when climbing in and out of the unit.

SECTION V

HOME UNIT INSTALLATION PROBLEMS

Increasing the thickness of the walls and partitions strengthened the unit, enabled mounting brackets to be cast in the wall, and made the unit too heavy to be picked up with a backhoe. The contractor installing the units then arranged for the vault manufacturer to set the units into place with his boom truck. This tended to limit the flexibility of the home owner, engineer, and contractor in selecting the unit location. Alternate solutions considered included using a large boom crane to lift the units over the houses from the county road; flying the units into the lots with a large helicopter from Louisville, Kentucky; using a barge equipped with a crane and placing the units from the lake; and using a crawler-type front end loader. The first three alternates were eliminated due to the weight of the unit, cost, and increased contractor liability. The last was eliminated by the county commissioners refusing to let any crawler equipped equipment onto the shoulder or surface of the county road.

Faced with having to reduce the weight of the unit, the contractor decided to set the top on the unit in the field. Mortar, concrete, hydraulic cement, tar, and epoxy cement were all used and proved unsatisfactory for field installations. The problem was solved by using RAM-NEC, a bituminous gasket material (manufactured by K. T. Snyder Company, Houston, Texas). In fact, a unit could be shifted by lifting rings in the top once the top was sealed with the RAM-NEC. A problem arose because of this virtue--if the interior partitions of the unit were not covered completely at their connecting point with the top, then voids would be left between the wet and dry sides of the unit. The top could not be removed so the crack had to be cleaned and then sealed with epoxy cement. This greatly increased the labor cost of installing the unit.

It is recommended that any field work involved creating a waterproof seal be eliminated if at all possible. If not, then a mechanical seal is recommended.

The home grinder-pump units were installed and connected to the piping between the house and the septic tank of the existing houses around the lake. Many of the houses and their septic systems had been constructed prior to the additional extra fill placed over the septic tank. This meant that many of the grinder-pump units had to be installed from 5 to 9 feet below the existing ground surface.

The access into the compartments in the unit was then through a concrete pipe placed over the openings. The concrete pipe proved to be just as difficult

to seal as was the unit itself. RAM-NEC proved to be the only product that was reasonably reliable in assuring a watertight seal.

Due to the limited flexibility in the adjustment to grade of the height of the riser pipe over the compartment openings, the unit fabricator cast some 6-inch tall pipe extensions for use in height adjustments of 6 to 18 inches. These proved to be a good idea in the office, but a failure in the field. The rings were 4 inches thick to prevent breakage during the field installation. When installed, these rings were never sealed completely. While not having any openings directly into the unit's compartments, a space was left between the sealant and the outer edge of the riser ring. Water would collect in this void and, upon freezing and thawing, break the seal between the rings. The only prevention was to apply a sand-mix coating around the outside of the joint. This proved to be expensive in both labor and time lost in completing the installation.

The problems involved with leakage, broken service lines, vandalism, and exposure to liability can be directly related to the amount of time that elapses between the digging of the hole for the home unit and the backfilling of such. Units left overnight without being backfilled proved, time after time, to cost the contractor lost time and money the next day. Eventually, the contractor refused to start installing a unit unless he could finish it (excluding the electrical installation) on the same day.

The electrical connection of the unit was contracted independently by each home owner. This was done due to the uncertainty of predicting the cost of such installations. The location of the electrical controls was left to the discretion of the home owner, and, therefore, no uniform location resulted. Locations chosen ranged from outside the house under the roof overhang to inside a linen closet in the master bedroom. The best location, from the service man's standpoint, proved to be the garage. Two notable exceptions to this were when the location chosen in the garage was above the family's food freezer and when the home owner had a habit of locking the family's canine member in the garage without warning the service man.

In summary, the location should be such that access to the controls is available without entering the home and without having to climb over articles stored in front of the controls. NOTE: A fused electrical disconnect should be located next to the controls for use by the service man.

It was originally anticipated by the engineer that the majority of the existing utilities at each home could be located, to some degree, by the home owner. This would have enabled the contractor to avoid cutting most of those services by locating the pressure sewer service line elsewhere. Nothing could have been further from the truth. With very few exceptions, the home owner's information proved to be of no value to the contractor.

One home owner, absolutely positive of the location of all of his utilities, located the path for the trencher to follow. Consequently, the contractor followed that route and cut the water line, the telephone line, the electrical line to the man's boat house, the electrical line to a light by his driveway, and his gas line three times. This was the record for services cut. The

average number of services cut per house was 1.3.

It is suggested that any contractor installing such a system be given a flat amount for each service repair required when the service line is installed according to the home owner's instructions.

A curb cock valve (See Figure 3) was installed in all of the service lines between the system main and the home unit. PVC valves produced by Water and Gas Products of Tulsa, Oklahoma, were used in these installations. These valves developed leaks around a metal ring used to hold the gate in the body of the valve. When informed of this problem, the manufacturer modified his valve and solved the problem.

An extension of 4-inch pipe was placed over each valve to enable a valve key to be used to open and close the valve without having to dig it up. The extension was then capped to prevent the dirt and water from collecting over the valve. Two types of caps were used:

1. A solvent-weld one-piece cap pressed over the end of the pipe without solvent
2. A threaded plastic sewer clean out

The second solution proved to be the best because the cap remained functional, even when people stepped on it. The first type would become wedged on the pipe under similar circumstances and was difficult to remove.

Several service lines were broken when cars ran over the extension above the curb cock valve. A solution to this problem would be a collapsible valve extension, as shown in Figure 3.

Several types of service line material were used on the project. The following is a summary of the various materials used and an evaluation of each:

<u>Type</u>	<u>Nominal Size (inch)</u>	<u>Flexibility</u>	<u>Type of Fittings</u>
PVC-SDR 21 (20-ft. lengths)	1	Limited	Solvent Weld Coupling
PVC-SDR 13.5 (20-ft lengths)	1	Limited	Solvent Weld Coupling
PVC-SDR 21 (20-ft lengths)	1.5	Limited	Solvent Weld Coupling
Polypropylene (roll)	1	Good	Cold-Flared w/brass
Polybutylene (roll)	1	Good	Cold-Flared w/brass

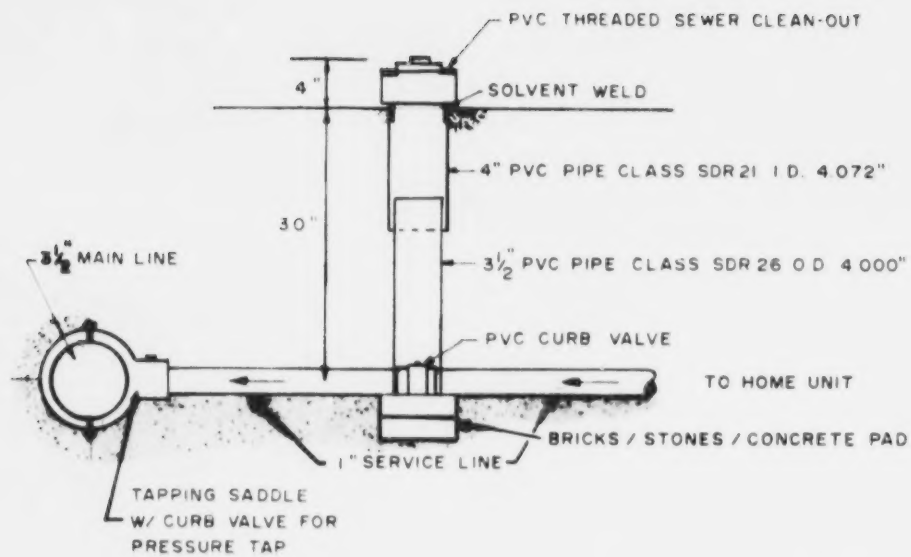


FIGURE 3. CURB VALVE AND RISER INSTALLATION

PVC-SDR 21 - This was the easiest pipe to obtain because it is a standard stock item of most local plumbing supply firms. There were several instances where service lines of this material broke due to settling of the home unit. We would not encourage its use.

PVC-SDR 13.5 - This is not a standard item stocked by most local plumbing supply firms. However, the 0.097-inch wall thickness compared to the SDR-21 pipe (0.063-inch) is worth the difference in price (approximately 5¢/foot). There were no breaks or leaks in any service lines due to unit settling, stone bruises, etc., when this pipe was installed. This was the best service line material used in the opinion of the service men.

PVC-SDR 21 (1.5 inch) - Satisfactory performance.

Polypropylene - This pipe with cold-flared brass fittings was relatively easy to work with, but care had to be taken not to bend the pipe excessively. The pipe would not break, as would the PVC pipe, but it would develop a kink which would restrict flow and eventually rupture under pressure. Although it costs more than the PVC, no time is wasted waiting for a solvent to set up. This is a good service line material if the installation is proper.

Polybutylene - Same conclusions as for polypropylene

SECTION VI

GRINDER-PUMP UNIT EVALUATIONS

The Original Unit

The locally fabricated home grinder-pump unit did not prove to be effective in grinding and pumping the domestic waste for the following reasons:

1. Leakage between the wetwell and drywell
2. Electrical control failures
3. The placement of the grinder
4. When the pressure in the main line exceeded the maximum head of the centrifugal pumps then the pumps overheated causing leaks in the plastic piping in the units

The largest single factor in the failure of the locally manufactured grinder-pump unit was due to leakage problems. Both external and internal leakage into the drywell caused repeated electrical failures. Although various methods were used to solve the leakage problem, the pre-cast concrete container was both too heavy and too difficult to make water tight to be considered in future installations.

Electrical control failures were the second most frequent cause of unit malfunctions. Several problems with the electrical equipment resulted from the electrical panel being located in the unit. The panel was located there to enable servicing of the electrical equipment with maximum efficiency by allowing easy observation of equipment performance relative to electrical adjustments. However, in any installation of electrical equipment in a drywell below grade, provisions for humidity control should be considered regardless of size. Funds available did not permit this on the Grandview project and therefore the electrical panel had to be removed from the drywell. This resulted in additional service time during maintenance.

It had been assumed that a relatively dry compartment would be available within which to mount the panel. Watertight enclosures for the electrical equipment were utilized, but condensation within the equipment enclosures caused contactor malfunctions. A small light bulb was installed in the contactor housing, and this alleviated the moisture problem in the contactor.

It was anticipated that all of the equipment within the unit would be provided with fused protection. While being sound in theory, the idea proved to be unworkable in the field application. A single fused disconnect proved to be the best arrangement for providing electrical overload protection.

The electrical contactor was sized based upon the manufacturer's recommendation relative to the anticipated amperage used during the operation of the pump and grinder. As discussed previously, the garbage grinder used twice the amperage expected by the manufacturer when the liquid head exceeded 8.25 inches above the cutting blades. This caused the total amperage to exceed the rated capacity of the contactor. This in turn, caused the contactor to fail. Additionally, the frequency of grinder and pump operation was increased when the storage above the grinder was reduced. The sturdier construction of the next larger size contactor proved to be well worth the additional cost. This was an instance when deliberate over-design by the engineer would have been beneficial in the operation and durability of the product.

Several of the contactors that failed structurally were returned to the supplier and forwarded to the manufacturer. It was interesting to note that the following year's model of contactor had been strengthened at the points of failure observed by the maintenance crew.

Electrical probes and float switches were used in the unit and both proved to be relatively trouble-free. The effectiveness of the probes was somewhat less than that of the float switches. This could be attributed to the solids accumulating on the probe surface. While solids accumulated on the float switches, it was not a problem. The probes initially were submerged and after the unit had been emptied were not in contact with any liquid. This enabled the solids to dry and form a crust which was relatively resistant to electrical conductivity. The float switch used to shut off some units remained in contact with the liquid so that the solids did not dry and accumulation was minimal. It is suggested that a pressure switch or float switch is superior to a probe control for use in a home unit.

In summary, the electrical design of any home grinder-pump unit should be as simple as possible and capable of operating under the worst possible conditions. Design sizing should include at least a 50% safety factor in estimating anticipated amperage loads.

The locally produced grinder-pump unit was designed to store the raw waste from the home until 120 gallons (later reduced to 80 gallons due to problems associated with maintaining a liquid head above the grinder) had been collected. At that time, the grinder and pump started simultaneously.

The problem with this system was that every solid object that was put in the home drainage fixtures had to eventually pass through the grinder. Regardless of the degree of customer education in the proper use of the grinder-pump unit, objects got into the unit that could not be ground. This caused the grinder to jam and either blow a fuse or activate the thermal overload protection protector. This meant that the home unit would then overflow into the standby leaching bed until the unit was repaired.

It is not realistic to provide for grinding the total solids accumulation from the home; therefore, some provision for removing heavy objects prior to the grinding step should be provided. It is interesting to note that the Environment/One, Hydr-o-matic, and the Tulsa units all use the suction lift of their

pumps to pass the sewage through their grinders, i.e., the grinder is suspended above the bottom of the sump. This enables a heavy object such as a nail to remain on the bottom of the sump and avoid entering the grinder. This is a definite asset for all three units.

Leaks developed in the piping of several of the locally manufactured units rather consistently. It was discovered that this was caused indirectly by the pressure in the main line of the collection system. When the pressure exceeded 35 psi, the non-flushing centrifugal pumps (shutoff head of 35 psi) would continue to run without pumping any liquid. When this condition persisted for a significant period of time, a considerable amount of heat was generated and caused the plastic pipe to be weakened where it was connected to the pump. The point of leakage was always in the threaded connection which joined the metal and plastic pipes. This problem was eliminated by the maintenance of a low pressure in the main line.

While the overall performance of the locally manufactured grinder-pump units was unsatisfactory, it is interesting to note that one unit worked successfully for 10 months prior to replacement with no malfunction. However, the physical dimensions of the unit (4 ft. x 4 ft. x 4.5 ft.), its weight and the grinder location were not suitable for general application.

Flushing Units

The original system was designed with two flushing units on each main line. Each of these units consisted of a 1,000-gallon storage tank connected to a pumping unit that was activated every 24 hours by a timer. The two units' timers on each line were synchronized to allow simultaneous pumping. A minimum flushing velocity of 3.01 feet per second was anticipated in the 3-inch main lines.

The pump used was a Flint and Walling (Model 101) two-stage centrifugal pump which operated very well. While the pump was started by a timer, it was turned off by a float valve. Some difficulties in adjustment were experienced with the timers utilized on the unit. Power interruptions caused difficulties with the timers by altering the operating period of the units. A backup system of power for the timer, such as a wound spring, would have been beneficial. This feature was used when a replacement timer was required.

The flushing units were the most successful of the locally manufactured units. These units were designed with higher available heads than other units which permitted their operation during periods of restricted flow, due to air locks in the main line. However, they pumped when the normal system flow was lowest and subsequently the line pressure was low.

The problems discussed earlier which plagued the locally manufactured units were also found to a lesser degree on these units. Water leakage into the unit was reduced because RAM-NEK sealant was used, and piping leaks were reduced because Schedule 80 PVC pipe was used.

Actual flushing flows did not meet the Engineer's expectations. The anticipated daily flows from the homes having flushing units were not as great as

expected. One resident having a flushing unit did not occupy his home during much of the winter, despite a past history of occupancy during this season.

A better solution would have been for the flow from several homes to have been collected in a common storage tank for flushing liquid.

A total system of units utilizing the large storage capability and the time-controlled pump offers countless possibilities of regulating flow rates within a system. An extension to the original system was installed, and the Engineer recommended such units be installed at each house connected to the extended line. Their flow was to be stored and pumped at night when other flows were reduced.

The Environment/One Unit

The Environment/One Unit was marketed in a way that was very attractive to the lot owners' at Grandview Lake. The manufacturer offered to furnish and install the residential pumping units. Later, a service agreement was offered by the manufacturer through its contractor-representative. This idea of a total package program available to the owner, where no operating utility maintenance program existed, was superior to contracting each unit individually. The convenience of dealing with one supplier-installer-service-man far outweighed any potential cost savings to be realized through separate contract negotiation by each owner. An Environment/One Unit, as installed, is shown in Figure 4.

The E-1 Unit, Model 210, is a 1 horsepower motor-driven progressing-cavity pump with a cutting blade attached to the suction end of the pump's rotor. The progressive cavity pump is manufactured by the Moyno Pump Division of the Robbins and Myers Company, located in Springfield, Ohio. Similar pumps were used in the 20 locally manufactured units and proved to be very reliable.

The Moyno pump is designed so that the metal pump rotor turns within a rubber stator creating a progressive compression action. Although there is some safety factor available due to slippage between the rotor and the stator during periods of restricted pump discharge, for all practical purposes, the pump should be considered a positive displacement type.

If during the operation of progressing cavity pumps an abrasive particle can become imbedded in the stator and score the rotor, this may eventually lead to failure of the stator itself. The E-1 Unit was equipped with a modified stator designed to reduce failures due to abrasive scoring. However, by increasing the durability of the stator, the amount of slippage between the stator and the standard size rotor is reduced. This intensifies the positive displacement characteristic of the pump and results in the need for a thermal overload switch as an integral part of the unit.

In several instances where the pump discharge was restricted completely, the rotor failed. The point of failure appeared to be within the area of contact between the rotor and the stator. Abrasive particles scored the surface of the rotor in every instance observed. The abrasive action of the foreign

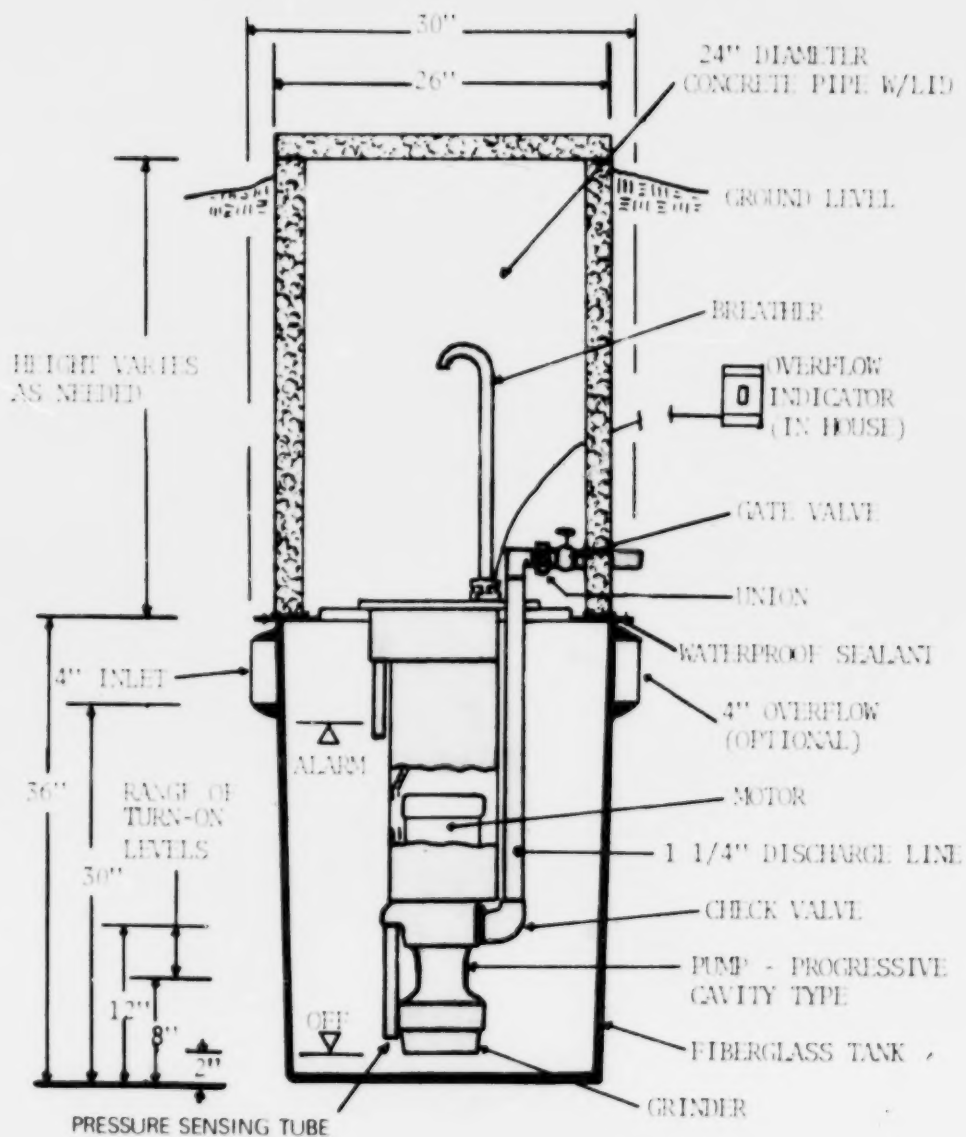


FIGURE 4. ENVIRONMENT/ ONE UNIT (Courtesy of Environment/ One)

particle was evidently intensified by expansion of the stator due to increased temperature.

The unit uses a thermal overload on the pump motor to limit the exposure to high operating temperatures. However, experience did not indicate that the thermal overload reacted quickly enough in all instances to prevent damage to the stator. There were several instances where unit failure was attributed to prolonged continual pump operation resulting in the main bearing seizing and locking up the pump. In these instances, the overload switch failed to operate in time to prevent damage to the unit.

During the project, an anti-siphon feature was added to the unit by the manufacturer. This eliminated the maintenance required due to air-locking that was experienced on the original Environment/One Units.

The unit housing is light weight fiberglass tank with a steel plate on top. One person could easily install one of these tanks on the construction site. However, the grinder-pump itself weighs 140 pounds. The units were normally installed 30 to 36 inches below grade, and this, coupled with the pump weight, necessitated more than one person to install or remove the pump for maintenance purposes. An alternative would have been to provide a single maintenance man with a mechanical lifting device to remove the unit.

The unit is designed for installation in the basement of the house served. Customer preference, lack of suitable space in existing homes, and access needed for maintenance purposes resulted in outdoor installation of most of the units. Access to the unit below grade was made by placing a pre-cast concrete tile over the unit and sealing it to the unit with a petroleum base sealer. Mechanical equipment was needed to lift the concrete tile into place and the sealant was applied carefully to prevent water leaks into the unit.

Each unit is equipped with a warning light that may be located in the house. This light indicates unit malfunction and is provided as a convenience for the home owner.

The unit electrical controls were located near or in the home electrical panel.

The Hydr-o-Matic Unit

The Hydr-o-matic units utilized at Grandview Lake were used under two situations - grinding and pumping raw sewage, and pumping septic tank effluent. The grinder-pump units were less successful than those pumping only septic tank effluent, but both types of installation required maintenance. The unit was very rugged, but had operational problems. Figure 5 is a schematic diagram of the major elements of a Hydro-o-matic grinder-pump installation.

The basic grinder-pump unit was a 1.5 horsepower submersible centrifugal pump with grinder blades preceding the pump. The tank housing was made of steel and the unit piping was galvanized. The grinder-pump discharge piping was connected to the plastic service line by a hydraulically sealed discharge flange. Backflow from the system main during pump removal was prevented by a gate valve, located within the tank, whose valve stem was extended to

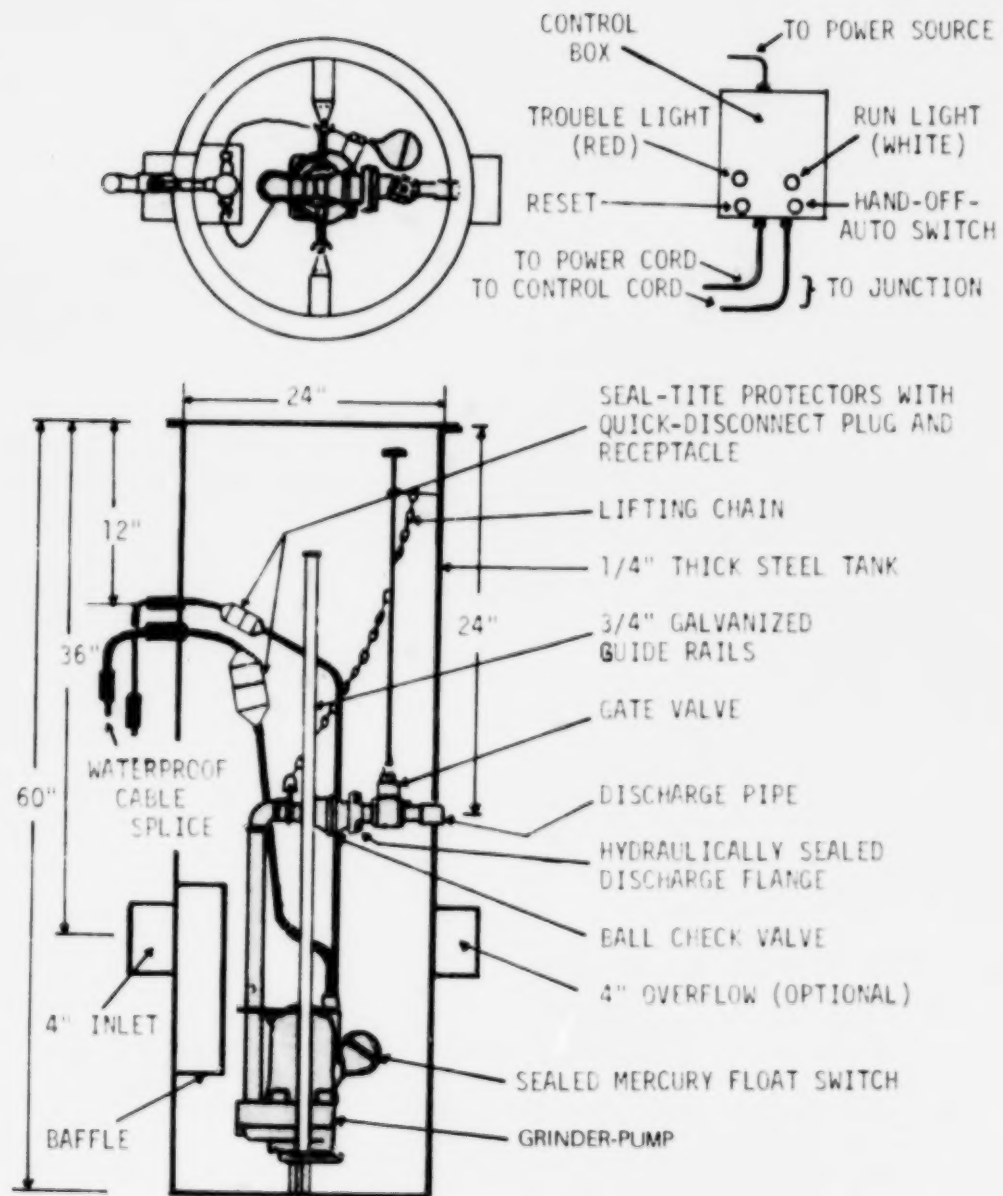


FIGURE 5. HYDR-O-MATIC UNIT (Courtesy of Hydr-O-Matic)

within inches of the top of the unit housing. The positioning of the grinder-pump in the unit was controlled by guide rails on opposite sides. A sealed mercury float switch was used to control the grinder-pump operation. Back-flow into the unit from the system main was prevented between normal operating cycles by a ball check valve between the grinder-pump and the hydraulically sealed discharge flange.

After the gate valve was closed, the grinder-pump was removed by pulling on a chain attached to it. Although the guide rails aided in removing and installing the grinder-pump, removal by a single maintenance man was still difficult due to the weight of the grinder-pump and attached piping (approximately 85 pounds).

The location of the unit's check valve created the biggest problem with the unit. During periods of excessive main line pressure, the hydraulically sealed discharge flange leaked badly. This caused the unit to operate continuously. If the check valve had been located between the discharge flange and the gate valve, this could have been prevented. Several instances of check valve failure and leakage due to fouling with solids and stringy matter also occurred. The ball check valve was not as satisfactory as the swing check type.

One pump had a problem with air locking. This caused continual operation with no liquid movement and subsequent overheating and pump failure. The pumps were not equipped with an anti-siphon device. This was prevented in the problem unit by drilling a 0.125-inch hole in the discharge pipe between the pump and the ball check valve.

The pump control, a sealed mercury float switch, proved to require a lot of maintenance. The construction of the float was faulty in that it leaked. The manufacturer has since corrected this problem. Since the float was installed to operate between the grinder-pump and the tank wall, one unit, installed in smaller (20-inch) diameter tanks, malfunctioned due to a build-up of grease and solids on the tank wall. This crust built up until it prevented operation of the float switch. The manufacturer's representative suggested that the home owner hose down the inside of this unit periodically to prevent such a build-up.

Installation of the unit was restricted because there was no provision for extending the height of the unit housing beyond that specified prior to fabrication. This was a major problem to the contractor installing the unit. Care should be taken in specifying the tank dimensions and type to allow for depth variations upon installation.

The unit controls, excluding the mercury float switch, were housed outside the unit, usually in the customer's house. A red trouble light came on during periods of pump malfunction and a white one during normal operation. A reset button was provided for use when the unit had stopped due to a temporary condition such as overheating of the pump motor. When the reset button would not start the pump, the maintenance people were notified.

The Tulsa Unit

The Tulsa unit was a lightweight submersible grinder-pump housed in an FRP tank with an adjustable access riser. Plastic products were used whenever possible in the unit.

The grinder-pump consisted of a 1 horsepower motor, housed in a stainless steel outer casing, with a grinder-pump attached. An installed Tulsa unit is shown in Figure 6.

The motor proved to be dependable but slightly undersized. The grinder-pump was not dependable. The grinder blades were held in place on the shaft by a metal key. The pump's vibrations during operation caused the key to fall out and the shaft to spin without turning the blades. Subsequently, the manufacturer welded the blades to the shaft, but this made replacement very difficult.

The stainless steel outer casing acted as the unit's on-off switch. An adjustment for regulating the duration of operation of the pump was located in the handle on top of the motor. Vibrations during operation loosened the adjustment screw. This caused the grinder pump to run continuously or not at all.

The unit's centrifugal pump was rated at 12 gallons per minute at 35 psi. Actual experience indicated that performance was considerably below the rating.

The Tulsa unit provided the largest total storage capacity of all the commercial units (71 gallons). A concrete anti-flotation collar was also required for this unit, as shown in Figure 6.

PVC piping was used in the unit. A PVC "quick-connector" compression-type fitting was used to connect the discharge piping from the grinder-pump to the service line. A PVC corporation valve was used to prevent backflow from the system main line into the unit when the compression fitting was removed. A bronze check valve was used.

Initial problems were experienced with the discharge piping due to the location of the check valve. Originally, the check valve was located in the vertical discharge line close to the grinder-pump. This created two problems. First, the grinder-pump had to be removed to service the check valve. Second, the ground solids, particularly paper, collected on top of the valve gate, preventing it from seating properly. While the first problem was an inconvenience to the maintenance men, the second meant that backflow from the system forced the unit to cycle continually.

The check valve problems were nearly eliminated when the check valve was moved to a short horizontal section of piping (See Figure 6) accessible to the maintenance man without removing the grinder-pump.

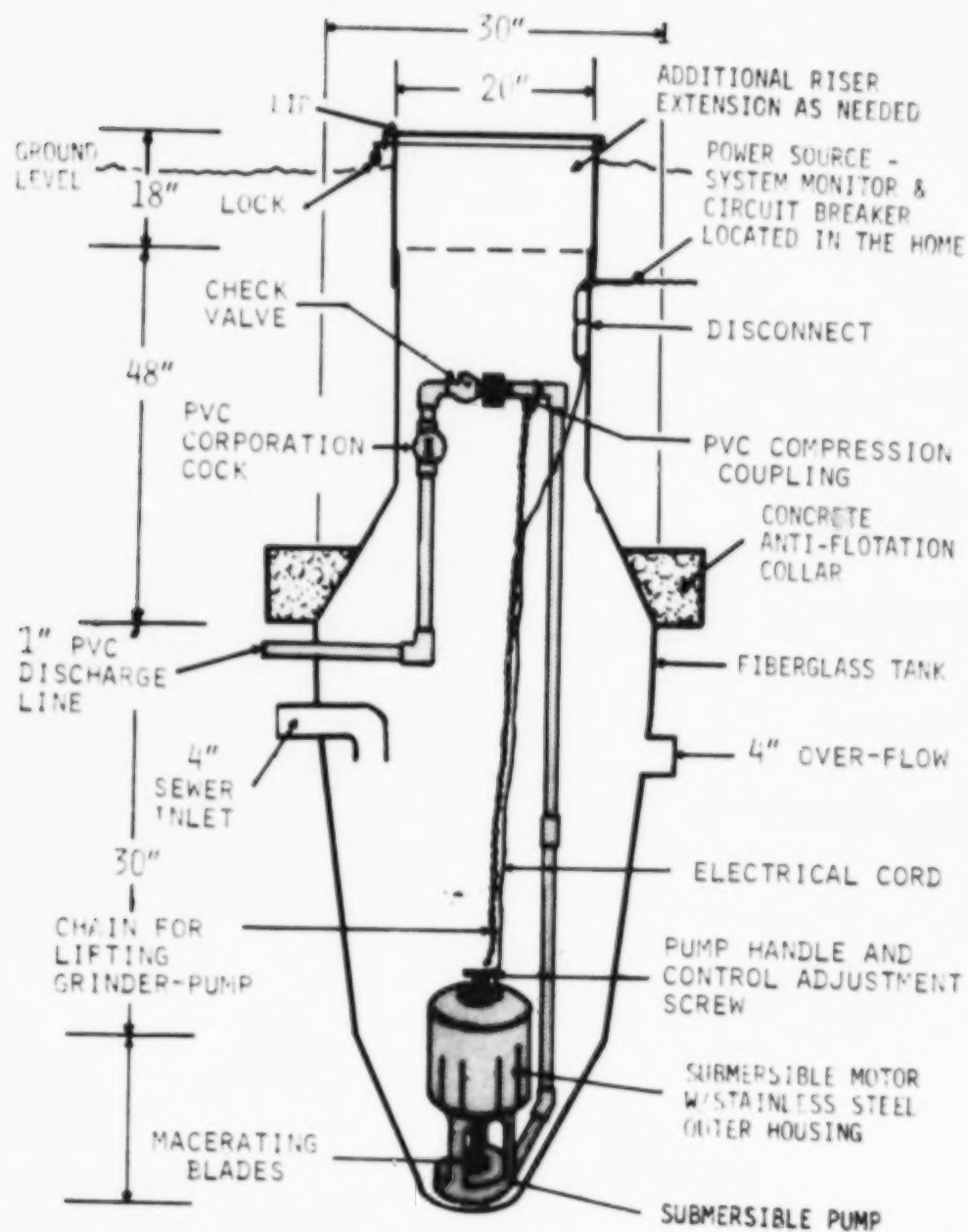


FIGURE 6. TULSA UNIT

The Tulsa unit did incorporate some very good features. The grinder-pump was light enough for one person to remove easily. The fiberglass tank was easy to install. The access riser was easily adjustable to different heights during construction. Also, when the grinder-pump operated, it did not incur a build-up of grease and solids around the sides of the tank as did the other units.

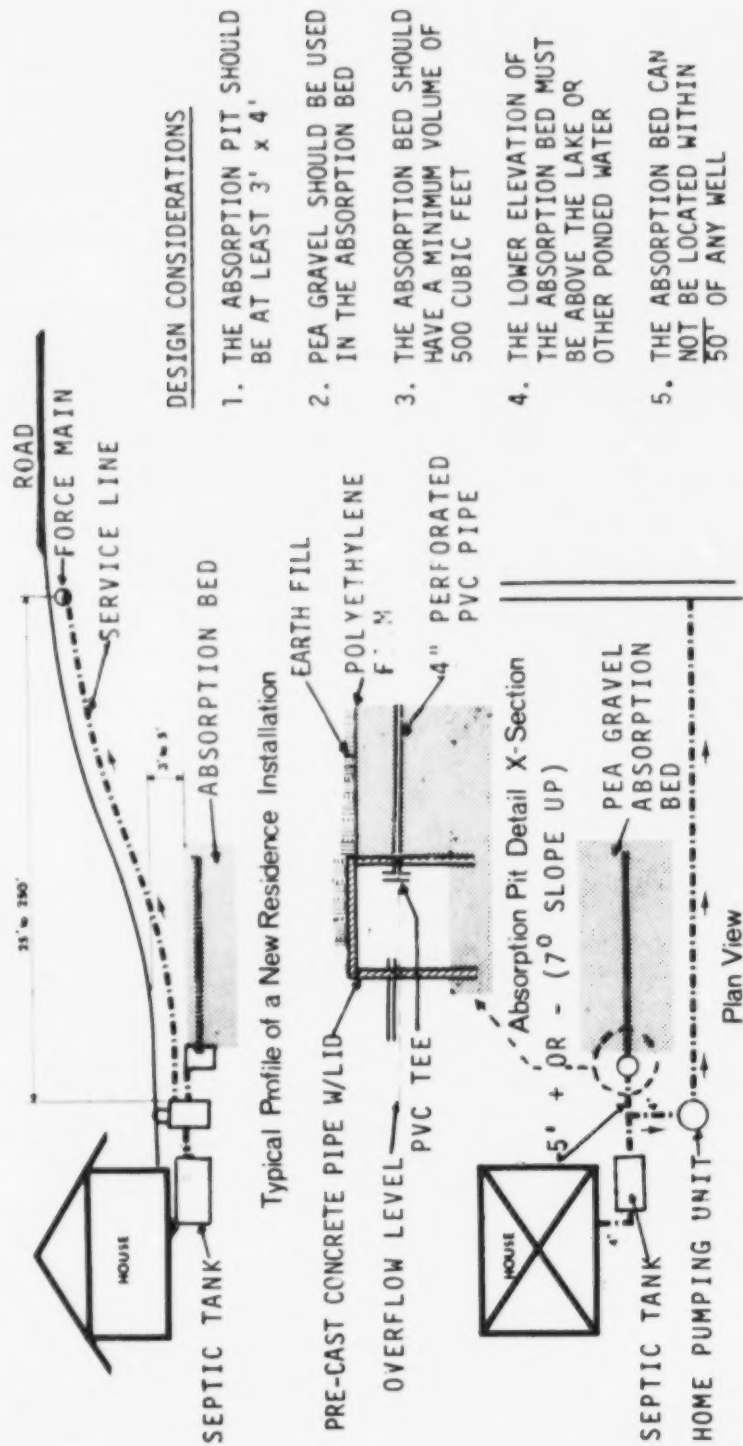
The unit was also equipped with a remote warning light and reset button.

Additional research and development is needed to bring the unit's reliability into an accepted range for an operating utility. Subsequent correspondence with the manufacturer indicates that such research is being initiated in a project at Wichita Falls, Texas. Results of this work are scheduled to become available in the near future.

Miscellaneous

An overflow adsorption system was recommended by the Engineer (See Figure 7) for all of the home units. However, considerable infiltration into these systems with overflowing into home units caused increased unit operation and increased flow at the treatment plant.

A summary of maintenance frequency by cause and type of unit is shown in Table 1.



NOTE: SEPTIC TANKS ARE NOT INSTALLED WITH HOME UNITS THAT GRIND AND PUMP RAW SEWAGE

FIGURE 7. OVERFLOW ABSORPTION SYSTEM DETAILS

DESIGN CONSIDERATIONS

1. THE ABSORPTION PIT SHOULD BE AT LEAST 3' x 4'.
2. PEA GRAVEL SHOULD BE USED IN THE ABSORPTION BED.
3. THE ABSORPTION BED SHOULD HAVE A MINIMUM VOLUME OF 500 CUBIC FEET.
4. THE LOWER ELEVATION OF THE ABSORPTION BED MUST BE ABOVE THE LAKE OR OTHER PONDED WATER.
5. THE ABSORPTION BED CAN NOT BE LOCATED WITHIN 50' OF ANY WELL.
6. STANDARD RECOMMENDATIONS OF THE STATE BOARD OF HEALTH ON SEEPAGE PITS MUST BE OBSERVED.

Table 1. SUMMARY OF MAINTENANCE FREQUENCY
(2-year period)

Cause	Locally Manufactured Unit	E-1 Unit ^a	Hydr-o -matic Unit ^a	Tulsa Unit
1. Pump Failure	52	4	8	2
2. Grinder Failure	25	0	1	2
3. Piping Failure (within tank)	41	4	7	1
4. Electrical Failure (excluding controls)	66	3	2	0
5. Control Failure	23	0	10	2
6. Piping Failure (outside tank)	11	2	8	0
7. Infiltration/inflow of water	56	1	0	0
8. Collection System Malfunction	7	1	2	4
9. Improper Installation	9	2	2	0
10. Miscellaneous	<u>81</u>	<u>0</u>	<u>12</u>	<u>5</u>
Totals	371	17	52	16
Maximum Number of Units	27	15	28	2

^aMaintenance of the E-1 units was done primarily by the manufacturer's representative. The hydr-o-matic units were serviced by the manufacturer's field personnel as malfunctions were reported to the factory. Therefore, the figures listed above were based on the field notes taken by the engineer's maintenance crew and may not include all of the service calls by others.

SECTION VII

PRESSURE COLLECTION SYSTEM

The sewage collection system at Grandview Lake consisted of 28,312 feet of 3- and 3.5-inch PVC pipe installed 36 to 42 inches below the ground surface. One main line on each side of the lake was installed to serve approximately one half of the total inhabited shoreline. The two lines both discharged into a 5-inch line which terminated at the treatment plant.

Pressure from the individual home units was sufficient to pump liquid and ground solids to the treatment plant without the use of mainline pumping stations. There were several problems associated with the collection system, but the practicality of the design concept of such a collection system was demonstrated sufficiently to encourage similar future projects.

It was the original contention of the engineer that main line check valves were not needed because the system would be under continual pressure and such valves would be an added installation and maintenance expense to the utility. For economy of installation additional gate valves were not installed at regular intervals on each line.

While the use of main line check valves should be minimized, their use at intersections of large mains (10-inches in diameter or larger) and at specific points of potential hydraulic problems should be considered during design. Gate valves should be provided on lateral main lines and at intervals sufficient to isolate twenty to thirty individual customers for any maintenance required.

Service line connections to the main line while the system was in operation necessitated several maintenance calls. There were leaks due to improper use of the tapping tool. However, once having experienced the results of an improper service tap, the installer took care in future installations so that no leaks occurred.

Additional leaks or breaks in the main line occurred three times due to heavy equipment damage, several times due to earthslides, once due to improper installation, and once due to theft of a twelve foot section of pipe at the end of one of the main lines.

During the above mentioned line breaks, the maintenance personnel checked the broken main line for residual solids accumulation. During the initial startup period, solids accumulated sufficiently to prevent flow in one of the two main lines. However, as the flow increased due to additional service connections and flushing units were installed, the problem was solved.

This confirmed the engineer's contention that some provision for flushing the main lines is vital especially in the early stages of such a system. On four occasions a gasoline-powered pump was utilized to flush the main lines with lake water.

While solids accumulation presented some problems, air locking of the main lines was the major difficulty. The original system utilized automatic and manual air-release valves (See Figure 8). Eventually, additional manual valves were installed with the recommendation that they be converted to automatic ones when funds were available. It should be noted that during normal operation the venting of the accumulated air and sewage gas produced a minor odor problem.

Maintenance of the automatic air release valves was not easy because a pressurized water source was not available at each valve for backflushing. Several instances of valves failing to open due to solids accumulation on the mechanical linkage arm occurred. Generally, the air release valves were a minor maintenance problem.

One section of the main line was plagued with breaks due to the soil shifting. Breakage due to this earth movement was later prevented by installing a looped section of flexible pipe instead of PVC. Interestingly enough, this loop seemed to solve the problem.

The pipe used on the main line was specified by the engineer to be a brown color. This was done to enable a person installing a service connection to identify it. This was especially important since the area was served by a rural water system installed before the sewer system that also used PVC pipe. Since the water pipe was a white color, the engineer felt that the brown pipe would be easy to distinguish.

The possibility of requiring such pipe to be color coded and labeled "Sewer Line" might be worth considering on future projects. Although this could hamper material procurement by the contractor, it should prevent accidental cross connection between sewer and water lines.

All PVC piping was specified to conform to U. S. Department of Commerce Standard CS 256-63 for PVC 1220 SDR 26 with 160 psi working pressure at 2000 psi tensile strength and a minimum wall thickness of 0.097 inches. Couplings and fittings of the deep-socket type were required. Backfilling of pipe with a temperature of more than 65°F was prohibited. Testing at 150 percent of normal operating pressure (but not less than 100 psi) for at least 30 minutes was required before completion of backfilling. After this test and backfill completion, the pipe was required to remain full of water under pressure. At the end of that time a leakage test was performed. The 150-psi leakage test required not more than 100 gallons per day per inch of diameter for 12-foot pipe lengths or 75 gallons per day per inch of diameter for 16-foot lengths of leakage.

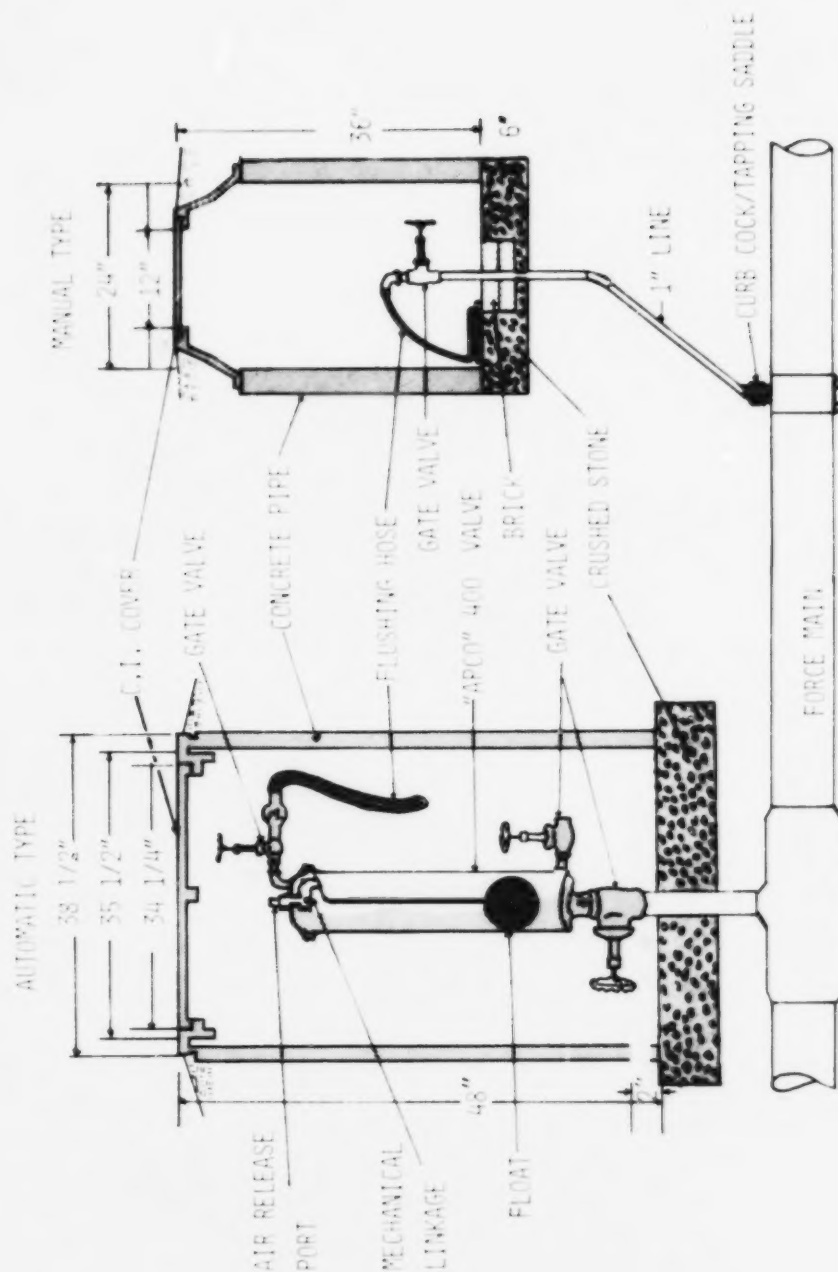


FIGURE 8. MANUAL AND AUTOMATIC AIR RELEASE VALVES

Installation of the pressure sewer system was accomplished with two types of trenchers, a backhoe and a small bulldozer with a small crew of manual laborers. When installing home units, similar needs existed with the addition of a front-end loader and, when concrete units were involved, a boom-truck.

SECTION VIII

VACUUM COLLECTION SYSTEM

Vacuum collection, another approach to the sewage collection problem, was attempted on a much smaller scale than the pressurized system. In this system, a central pumping unit maintained a vacuum in the main line and connected service lines. As the home unit filled with sewage, a valve connecting the unit to the vacuum line opened and the sewage was drawn into the line by the pressure differential in the line versus the atmospheric pressure. The sewage was then to be drawn into the central station and pumped under pressure into the pressurized main line of the rest of the system.

The primary advantage of a vacuum collection system was that smaller quantities of toilet flushing water would be required than with a conventional flush toilet. The engineer wanted to see if an adaptation of the vacuum collection system could offer a possible alternate solution to individual grinder-pump units by utilizing one central vacuum pump to serve several houses.

Studies by others had indicated success in moving liquids by creating "pockets" in the transmission lines for the liquid being moved to accumulate into "plugs." As liquid was drawn from one pocket point to the next, the tendency of the plug is to dissipate and the pressure to equalize. The increased installation cost of installing pockets in the collection lines was rejected. Instead, the collection lines were designed to remain filled with liquid at all times.

Operation of the vacuum system was not successful. The units failed to empty properly. Investigation into the reasons for the failure did not reveal a specific problem. Possible causes investigated included piping leaks, valve failure, incomplete priming of collection lines prior to start-up and line obstructions, but no satisfactory reason was discovered.

Additional problems of water leakage into the central vacuum unit caused repeated maintenance, and eventually the home units were replaced by pressure pumping units and the vacuum station was abandoned. Insufficient funds prohibited further investment in this area.

Specific problems or observations peculiar to the vacuum system were:

1. Initial starting of the vacuum system requires careful priming of the collection lines.
2. Installation of a vacuum system would require greater care than a corresponding pressure system.
3. Leaks in the piping are difficult to locate compared to a pressure leak.

The vacuum central station and the vacuum home units are shown in Figures 9 and 10.

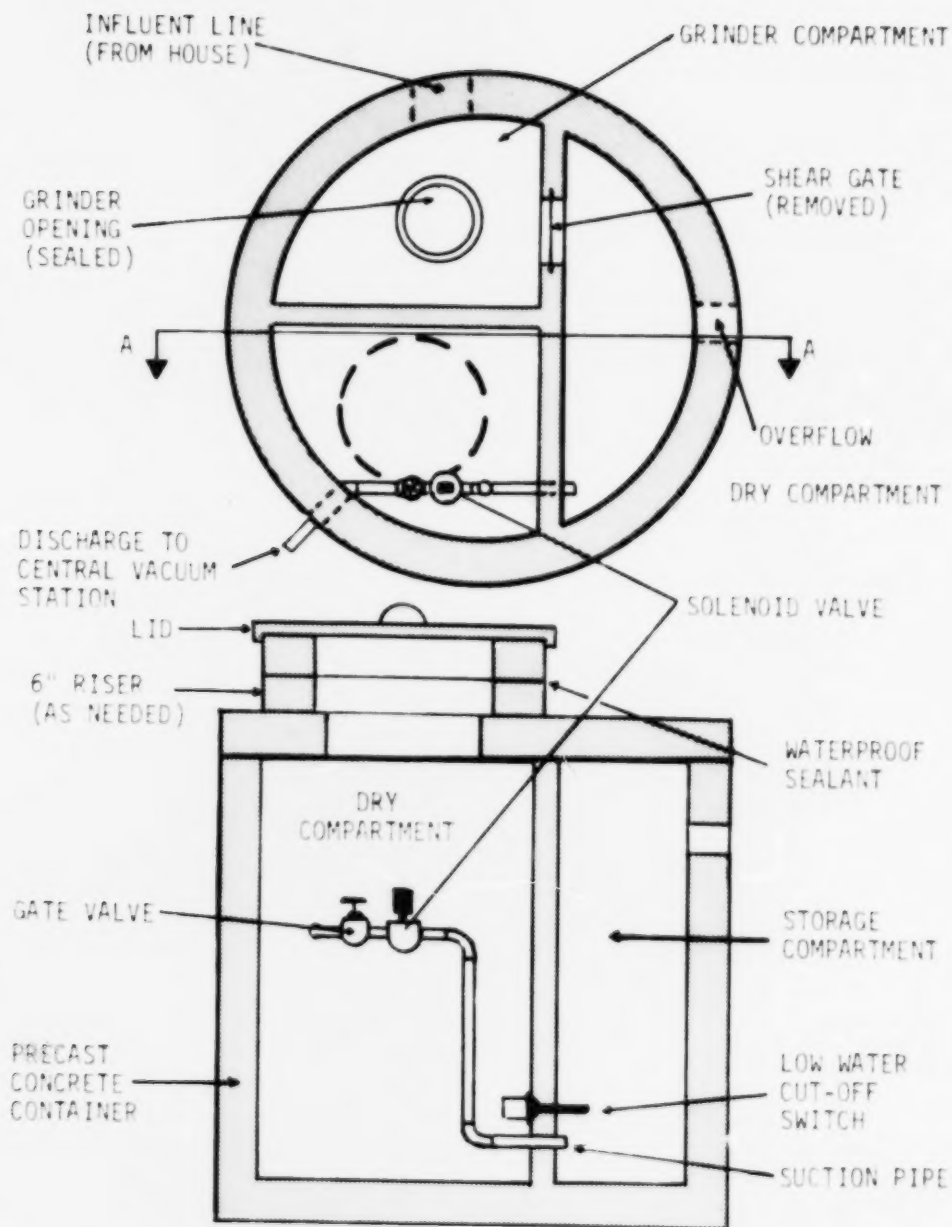


FIGURE 9. VACUUM UNIT

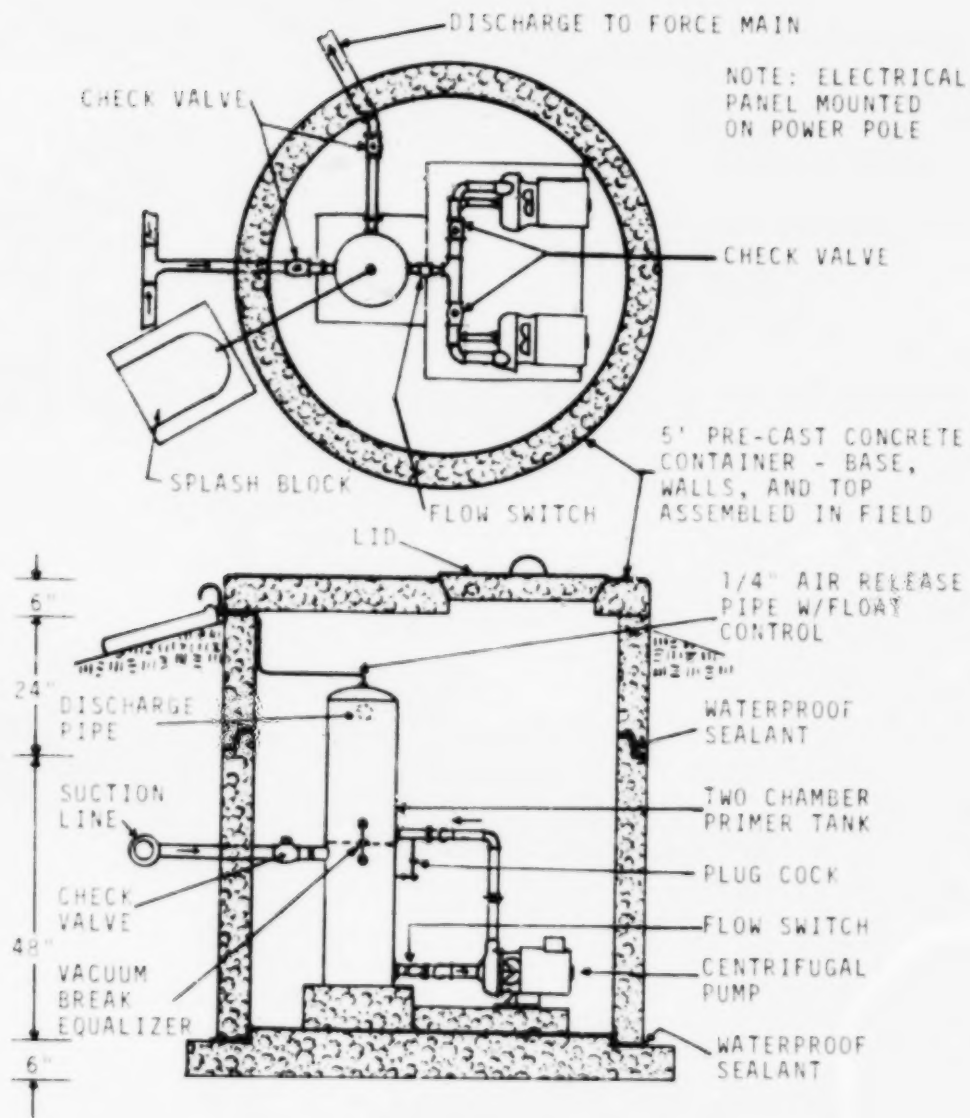


FIGURE 10. VACUUM PUMPING STATION

SECTION IX

STORAGE AND TREATMENT LAGOON

Facilities for measuring, treating and disposing of the sewage flow from the homes connected to the Grandview Lake Sewage System consisted of a parshall flume with a punched-tape level recorder, a storage and pumping unit, a two-celled lagoon, and an effluent irrigation system, and are shown in Figure 11. Modular approach to the plant construction was utilized by the engineer in an attempt to minimize construction costs. Operation of the plant was to consist of measuring the influent flow, storage of the sewage, irrigation of the lagoon effluent, and discharge of runoff from the irrigation area of not more than an amount equal to the natural runoff from rainfall during the irrigation period.

The degree of success of the treatment facilities was encouraging but failures in the physical facilities constructed created interruptions and curtailment of the effective study of the treatment process.

The parshall flume with a punched-tape level recorder was the first piece of equipment through which the flow passed in the treatment facilities. The parshall flume liner was fabricated by a local metal fabrication company and precast into a concrete rectangular channel and provided with a plywood cover. This greatly reduced the cost anticipated on such a structure, and several contractors indicated an interest in using such an installation on other projects. Field installation was limited to setting the unit in place, connecting the required piping, constructing the level recorder pit, and installing the recorder. There were two problems that affected the successful operation of the level recorder. There was rapid accumulation of ground up paper particles on the liner and the flume did not drain properly to prevent the buildup of liquid in the flume. The daily flow data were collected during a period when daily cleaning of the liner was performed by the SIECO maintenance men to solve drainage problems. A source of flushing water would have made maintenance of the unit easier. Any attempt to measure ground sewage flows must take into account this paper accumulation problem.

After passing through the parshall flume, the sewage was stored in a 1,600-gallon storage tank connected to a pumping unit. The pumping utilized a low head high-capacity Flint and Walling centrifugal pump controlled by probes in the storage tank. A sampling valve was provided so that a composite sampler could draw a sample representative of the total flow entering the plant in a 24-hour period. Paper particles fouled the control probes and sampling valve repeatedly and groundwater infiltration could not be completely eliminated.

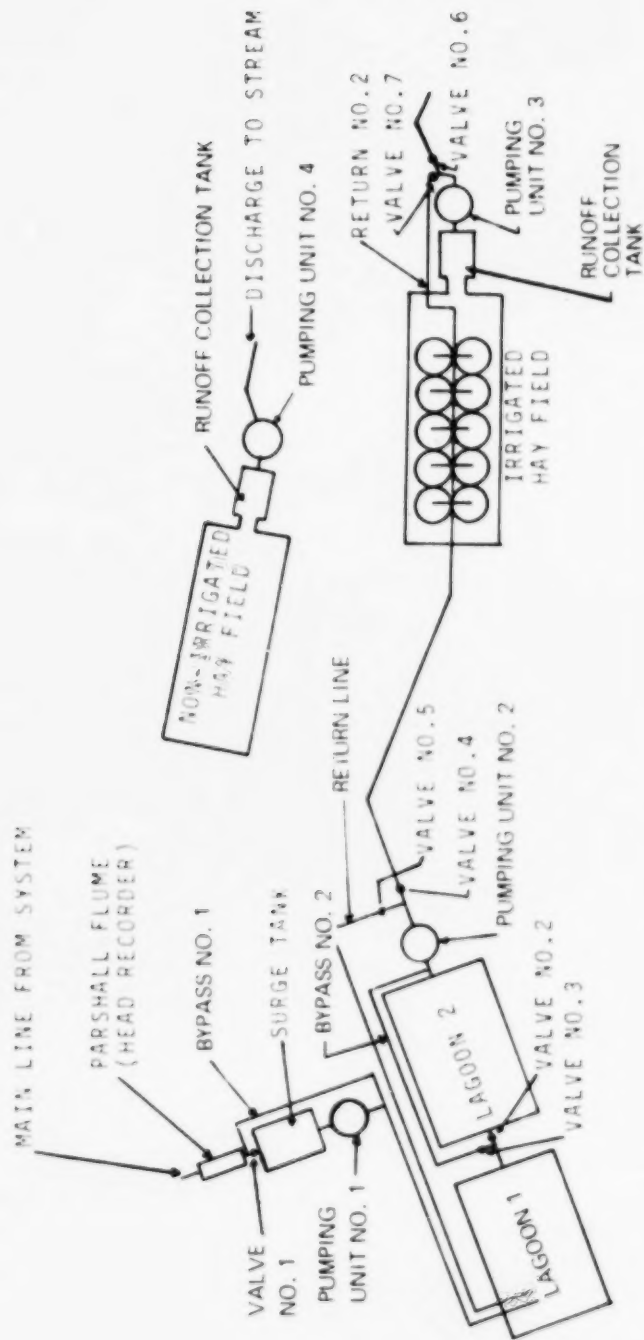


FIGURE 11. PLAN LAYOUT OF TREATMENT PLANT

A gravity overflow line was provided so that the storage tank and pumping unit could be bypassed. It was designed to be used only when the flow entering the plant exceeded the capacity of the pumping unit. This unit failed to work on three occasions. The first time there was an air lock in the pipe which was remedied by providing an air relief pipe that discharged back into the channel behind the recording device on the parshall flume. The second time a piece of heavy equipment had driven over the line and caused a break. The third time a dead rabbit was found in the opening to the line. It was never determined how the rabbit got into the system.

The pumping unit No. 1 and the bypass line were connected to a common line that discharged into the bottom of the primary cell of the lagoon. This pipe operated well for about 10 months but then became clogged with an unknown object or solids. Attempts to free the pipe failed, and a new pipe was installed.

The lagoon was a two-celled storage facility. The primary cell, the cell receiving the system flow, was designed as a facultative pond, combining anaerobic and aerobic biological activity. The raw sewage flow was to be introduced into the lower (anaerobic) level of the lagoon. Short-circuiting of the lagoon was minimized by use of a tee on the influent line. The upper (aerobic) level of the primary cell was to be utilized for irrigation into the hay crop and for sealing off any odor from the anaerobic section. The second cell was to be used for irrigation storage and polishing.

Flows anticipated at the plant were computed as follows:

22 year-around homes = 50,000/yr = 1,100,000 gallons

36 weekend homes = 50,000/yr x 1/3 = 600,000 gallons

Estimated annual flow = 1,700,000 gallons or 5.2 acre feet

Actual flow figures collected in 1972, shown in Tables 2 through 6, indicated a flow of about 60,000 gallons per home per year.

The primary cell was designed for a total volume of 1,070,000 gallons. Surface aerators were recommended at a future date as needed to maintain the upper zone of the primary cell in an aerobic condition. The secondary cell was designed for a storage capacity of 995,000 gallons. The two cells therefore had a total capacity of more than 2 million gallons. Space was reserved at the site for another 1-acre lagoon for future needs.

Initial filling of the primary lagoon was anticipated to take approximately one year under ideal conditions. However, due to the construction schedule of the facility, waste was discharged into the lagoon in November 1970. Since initial flow was limited, due to slow installation of the home units, the anaerobic section and a portion of the aerobic section of the primary cell of the lagoon was filled with 102,000 gallons of lake water pumped into the system. This was done to prevent damage to the lagoon piping during freezing and thawing of the lagoon surface.

TABLE 2
1972 MONTHLY FLOW DATA SUMMARY

Month	Total Flow (1)	Average Flow (GPM)	Average Flushing Peak Flow (GPM)	Highest Normal Peak Flow (GPM)	Number of Active Home Units	Average Flow per Unit (GPD)	Average Flow per Unit (GPM)
July	540,530	12.1	20.9	108.0	92	189.5	.132
August	429,629	9.6	25.0	100.0	92	150.2	.105
September	501,840	11.6	19.3	73.0	92	182.0	.126
October	451,732	10.1	20.8	96.0	92	158.1	.109
November	501,150	11.6	30.7	258.0	93	179.6	.125

NOTE: DURING NOVEMBER 1972, ON SIX OCCASIONS THE NORMAL PEAK FLOW EXCEEDED 100 GPM. DAILY INVESTIGATION BY FIELD PERSONNEL CONFIRMED PROPER OPERATION OF THE RECORDING EQUIPMENT AND NO BUILDUP IN THE PARSHALL FLUME DUE TO LINE OBSTRUCTIONS. FOR SUCH A FLOW THE PRESSURE IN THE MAIN LINE WOULD EXCEED THE SHUT OFF HEAD OF THE CENTRIFUGAL PUMPS USED ON THE PROJECT. THIS WAS ATTRIBUTED TO THE SIMULTANEOUS OPERATION OF THE POSITIVE DISPLACEMENT E-1 AND MOYNO TYPE PUMPS.

(1) Adjusted for any days when recorder was not in operation.

TABLE 3
DAILY FLOW DATA
FOR JULY AND AUGUST, 1972

Date	Total Flow (GPD)	Average Flow (GPM)	Flushing Peak Flow (GPM)	Normal Peak Flow (GPM)
7-15	15,000	10.4	17.0	50.0
7-16	12,400	8.6	24.0	85.0
7-17	25,200	16.1	29.0	39.0
7-18	15,700	10.9	33.0	70.0
7-19	18,400	12.8	23.0	39.0
7-20	14,400	10.0	17.0	85.0
7-21	14,400	10.0	15.0	50.0
7-22	23,200	16.1	17.0	108.0
7-23	18,800	13.0	13.0	68.0
7-24	18,800	13.0	21.0	77.0
8-05	13,100	9.1	17.0	35.0
8-06	14,100	9.8	24.0	39.0
8-07	12,500	8.7	23.0	61.0
8-08	12,500	8.7	24.0	39.0
8-09	12,400	8.6	17.0	28.0
8-10	11,200	7.8	21.0	31.0
8-11	11,500	8.0	29.0	31.0
8-12	16,600	11.5	26.0	54.0
8-13	13,700	9.5	21.0	35.0
8-14	12,700	8.8	19.0	42.0
8-15	13,700	9.5	45.0	31.0
8-16	14,000	9.7	31.0	77.0
8-17	20,200	14.0	31.0	35.0
8-18	12,400	8.6	40.0	68.0
8-19	14,800	10.3	37.0	77.0
8-20	13,100	9.1	38.0	35.0
8-21	14,800	10.3	17.0	42.0
8-22	15,800	11.0	36.0	100.0
8-23	13,000	9.0	24.0	42.0
8-24	13,500	9.4	17.0	39.0
8-25	14,800	10.3	23.0	50.0
8-26	15,000	10.4	13.0	68.0
8-27	18,800	10.3	21.0	68.0
8-28	13,800	9.6	21.0	50.0
8-29	12,000	8.3	21.0	39.0
8-30	12,400	8.6	17.0	35.0
8-31	11,800	8.2	21.0	50.0

TABLE 4
DAILY FLOW DATA
FOR SEPTEMBER, 1972

<u>Date</u>	<u>Total Flow (GPD)</u>	<u>Average Flow (GPM)</u>	<u>Flushing Peak Flow (GPM)</u>	<u>Normal Peak Flow (GPM)</u>
9-01	12,400	8.6	15.0	26.0
9-02	15,400	10.7	21.0	31.0
9-03	16,400	11.4	17.0	26.0
9-04	18,400	12.8	24.0	37.0
9-05	13,700	9.5	31.0	29.0
9-06	12,200	8.5	17.0	26.0
9-07	13,100	9.1	21.0	55.0
9-08	13,100	9.1	19.0	37.0
9-09	15,400	10.7	24.0	37.0
9-10	16,400	11.4	17.0	43.0
9-11	23,200	16.1	17.0	37.0
9-15	13,100	9.1	15.0	31.0
9-16	13,000	9.0	13.0	26.0
9-17	16,000	11.1	24.0	31.0
9-18	14,800	10.3	13.0	26.0
9-19	11,800	8.4	7.0	24.0
9-20	13,100	9.4	13.0	31.0
9-21	17,700	12.3	15.0	37.0
9-22	25,500	17.7	19.0	55.0
9-23	24,400	16.9	26.0	73.0
9-24	20,200	14.0	29.0	43.0
9-25	21,300	14.8	19.0	49.0
9-26	20,200	14.0	19.0	66.0
9-27	18,600	12.9	17.0	55.0
9-28	20,000	13.9	40.0	37.0
9-29	16,600	11.5	13.0	43.0
9-30	15,700	10.9	15.0	40.0

TABLE 5

DAILY FLOW DATA
FOR OCTOBER, 1972

<u>Date</u>	<u>Total Flow (GPD)</u>	<u>Average Flow (GPM)</u>	<u>Flushing Peak Flow (GPM)</u>	<u>Normal Peak Flow (GPM)</u>
10-01	18,400	12.8	39.0	68.0
10-02	18,600	12.9	35.0	77.0
10-03	18,400	12.8	35.0	54.0
10-04	17,900	12.4	24.0	68.0
10-05	16,400	11.4	18.0	61.0
10-15	12,700	8.8	30.0	41.0
10-16	15,400	10.7	25.0	41.0
10-17	13,200	9.2	25.0	44.0
10-18	12,500	8.7	25.0	38.4
10-19	12,400	8.6	35.0	41.0
10-20	12,400	8.6	20.0	44.0
10-21	12,100	8.4	20.0	44.0
10-22	11,800	8.2	32.0	35.0
10-23	15,000	10.4	25.0	50.9
10-24	13,500	9.4	23.0	50.9
10-25	13,500	9.4	16.0	30.0
10-26	14,400	10.0	20.0	35.0
10-27	14,000	9.7	17.0	58.0
10-28	12,800	8.9	20.0	35.0
10-29	13,800	9.6	27.0	41.0
10-30	16,000	11.1	20.0	93.5
10-31	15,000	10.4	30.0	96.0

TABLE 6
DAILY FLOW DATA
FOR NOVEMBER AND DECEMBER, 1972

<u>Date</u>	<u>Total Flow (GPD)</u>	<u>Average Flow (GPM)</u>	<u>Flushing Peak Flow (GPM)</u>	<u>Normal Peak Flow (GPM)</u>
11-01	14,300	9.9	29.0	101.0
11-02	17,100	11.9	31.0	80.0
11-03	13,700	9.5	44.0	47.0
11-04	12,400	8.6	23.0	41.0
11-15	12,200	8.5	21.0	55.0
11-16	15,000	10.4	26.0	59.0
11-17	15,400	10.7	34.0	84.0
11-18	30,000	20.8	26.0	108.0
11-19	27,900	19.4	76.0	257.0
11-20	17,300	12.0	29.0	134.0
11-21	14,700	10.2	29.0	49.0
11-22	16,000	11.1	29.0	52.0
11-23	15,100	10.5	19.0	43.0
11-24	18,400	12.8	26.0	49.0
11-25	19,900	13.8	34.0	73.0
11-26	16,100	11.2	31.0	62.0
11-27	15,400	10.7	26.0	62.0
11-28	16,400	11.4	31.0	37.0
11-29	10,100	7.0	26.0	76.0
11-30	16,700	11.6	24.0	52.0
12-01	19,300	13.4	26.0	59.0
12-02	16,800	11.7	29.0	88.0
12-03	15,700	10.9	40.0	55.0

During the winter the lagoons froze over and some of the neighborhood children went riding mini bikes on the ice. Fencing the facility site was not sufficient to prevent access. The Lot Owners decided that there should be an additional fence erected around the lagoons as soon as possible.

By June 30, 1971 there were twenty-three homes discharging into the lagoon. This flow coupled with surface run-off had caused sufficient accumulation of liquid to enable irrigation to be applied to the hay crop the week of July 18, 1971.

Operating procedures for the lagoon-irrigation facilities were designed for maximum flexibility. Descriptions of these procedures which follow are keyed to Figure 11. Under normal conditions the influent wastewater, after passing through the parshall flume, went first to the surge tank (valve #1 open). When the surge tank reached a set level, pumping unit #1 pumped the surge tank contents to lagoon 1. During power outages or peak flows which exceeded the 4-inch line capacity, the influent automatically bypassed to the lagoon via bypass #1. Lagoon 2 was designed for use during periods of high flow and during the winter for prolonged storage. The system also had the capability for recirculation from lagoon 2 to lagoon 1 by closing valves #2, 3, and 4, opening valve #5, and operating pumping unit #2. In addition, lagoon 1 could be mixed by closing valves #2 and 4, opening valves #3 and 5, and operating pumping unit #2.

Irrigation of the hay field could be accomplished from either lagoon 1 or lagoon 2. Lagoon 1 effluent could be used (minimum depth was maintained) by closing valves #2 and 5, opening valves #3 and 4, and operating pumping unit #2. Lagoon 2 effluent could be used by closing valve #5, opening valve #4, and operating pumping unit #2.

The non-irrigated hay field runoff was collected, sampled and metered to the stream via pumping unit #4. The volume of runoff discharged was then used as the "target" volume to be sampled and metered to the stream from the irrigated hay field runoff-collection tank via pumping unit #3 with valve #6 open and valve #7 closed. Any excess over the target volume in the irrigated field runoff collection tank was recycled to the sprinkler irrigation system by using pumping unit #3 with valve #6 closed and valve #7 opened.

Surface runoff continued to be a problem due to soil erosion into the drainage ditches around the lagoon. Maintenance of the ditches became critical and required additional grading by the contractor.

On January 9, 1972 a fault in the levee (See Figures 12, 13, 14, 15, and 16) around the secondary lagoon broke and approximately 750,000 gallons of irrigation liquid ran out through the break and eventually into the stream. This was reported promptly to the State Board of Health and the receiving stream was tested for contamination. A 5-day BOD test of the irrigation liquid just prior to the break was 6.5 mg/l. The 5-day BOD's taken at selected points in the stream ranged from a high of 4.2 mg/l at the point of discharge into the stream to 1.3 mg/l 1 mile downstream. A slight odor was evident 1 mile downstream but not evident 1.8 miles downstream.

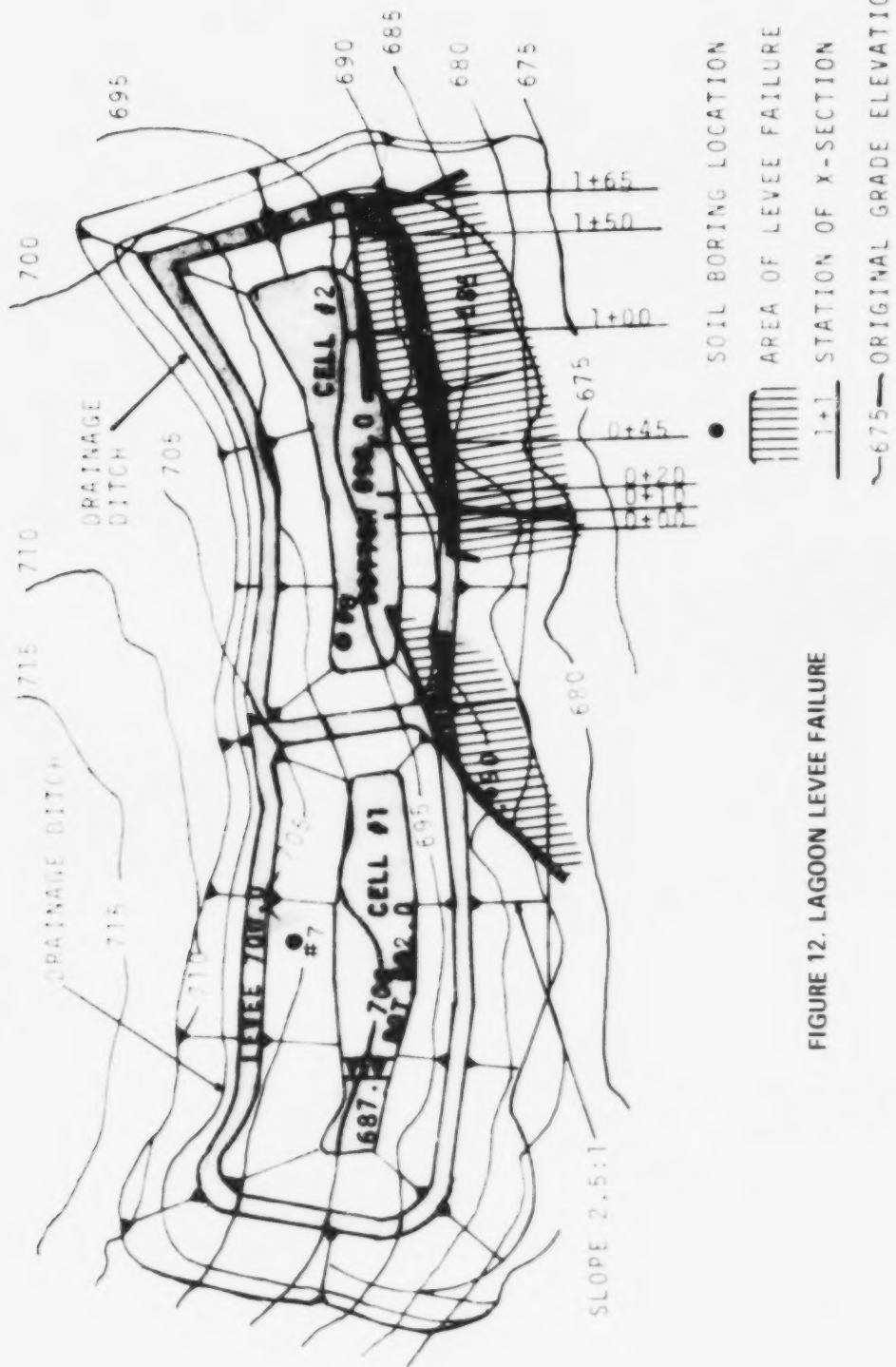


FIGURE 12. LAGOON LEVEE FAILURE

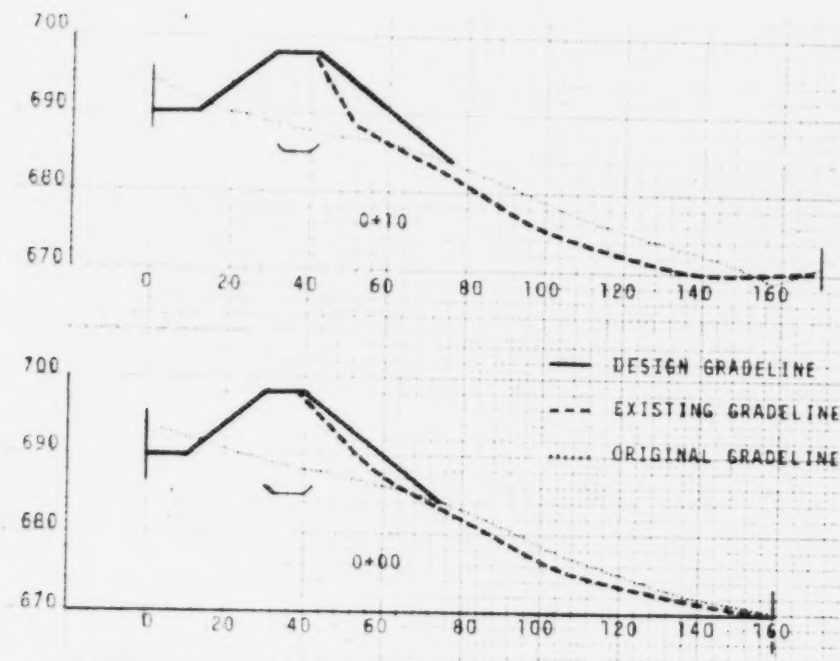


FIGURE 13. LAGOON LEVEE FAILURE X-SECTIONS AT STATIONS 0+00 AND 0+10

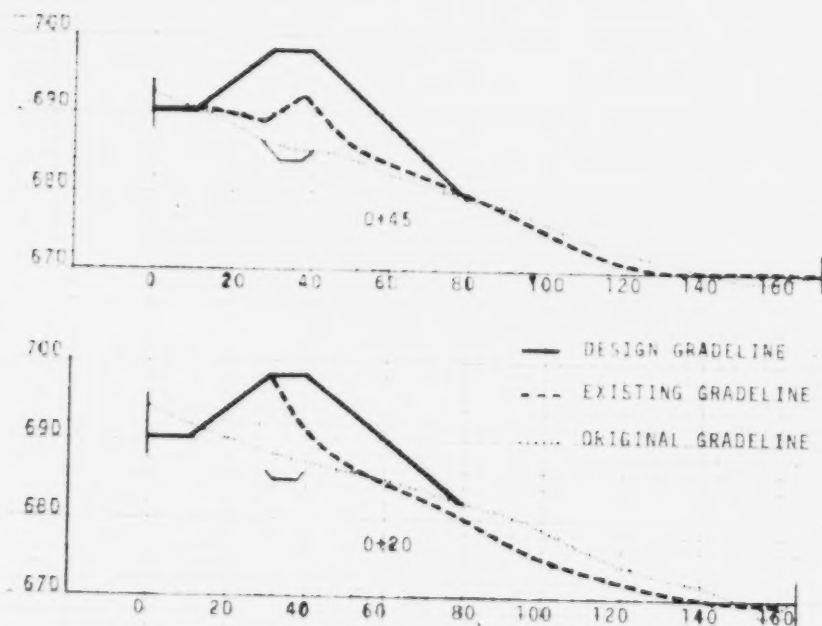


FIGURE 14. LAGOON LEVEE FAILURE X-SECTIONS AT STATIONS 0+20 AND 0+45

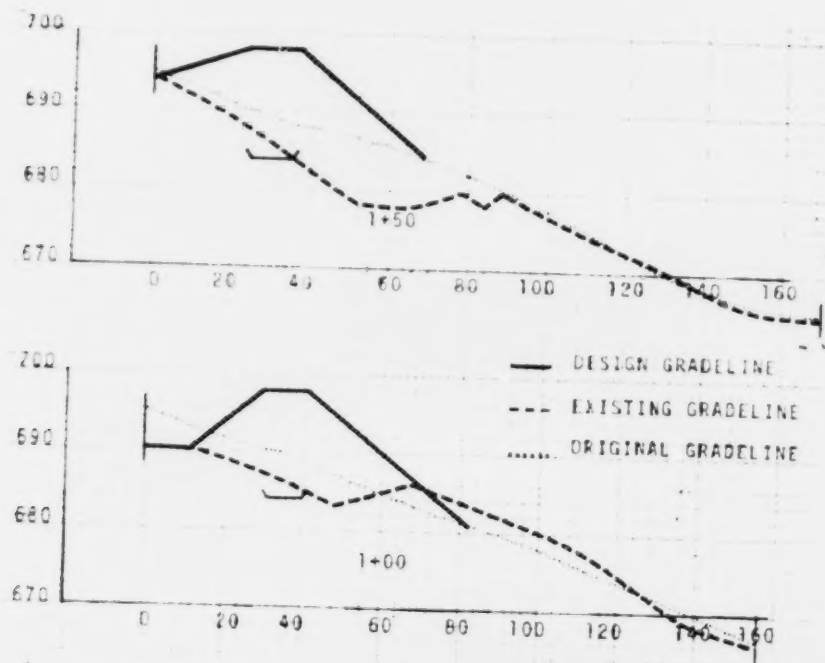


FIGURE 15. LAGOON LEVEE FAILURE X-SECTIONS AT STATIONS 1+00 AND 1+50

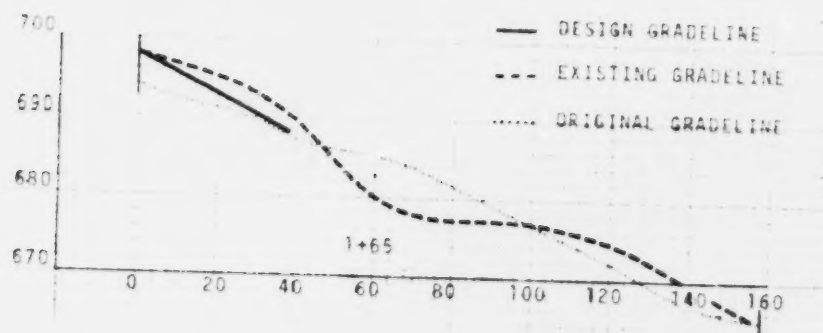


FIGURE 16. LAGOON LEVEE FAILURE X-SECTION AT STATION 1+65

Investigation into the cause of the slide revealed:

1. Irrigation of the plant effluent had been curtailed due to poor weather conditions and soil conditions.
2. The lagoons were full to the point of utilizing about one-third of the freeboard available.
3. Recent rains had kept the levee around the lagoon saturated.
4. The layer of shale noted in the original core borings was removed by the contractor in Cell 1 and clay compacted in its place. In the area of the levee, the contractor cut through the shale layer, removed the shale, and cut and constructed the levee key below that layer.

Soil conservation officials and the engineers observed that apparently a second layer of shale (soapstone) existed beneath the two lagoons that was not revealed in core boring No. 8 (See Figure 17) taken prior to construction. This material became saturated and very slick. The weight of the levee and the impounded liquid caused the entire section of the levee to slip down the soapstone layer. A solution to the problem proposed that a series of drains be installed in the soapstone layer and in the toe of the levee. This was deemed too costly and a larger lagoon was built at a different location on the plant site.

The new lagoon was designed to provide storage of four months of flow from one hundred houses plus rainfall. The lagoon had a surface area of 1.78 acres and had a total depth of ten feet of which 2.4 feet was freeboard. Additional irrigation area was also recommended at that time (See Figure 18).

Maintenance of the treatment plant proved to be much higher than anticipated in the original design estimate. The fact that the treatment process was simple did not enable limited maintenance of the equipment. A higher initial installation cost with an automated irrigation system might have resulted in lower overall costs.

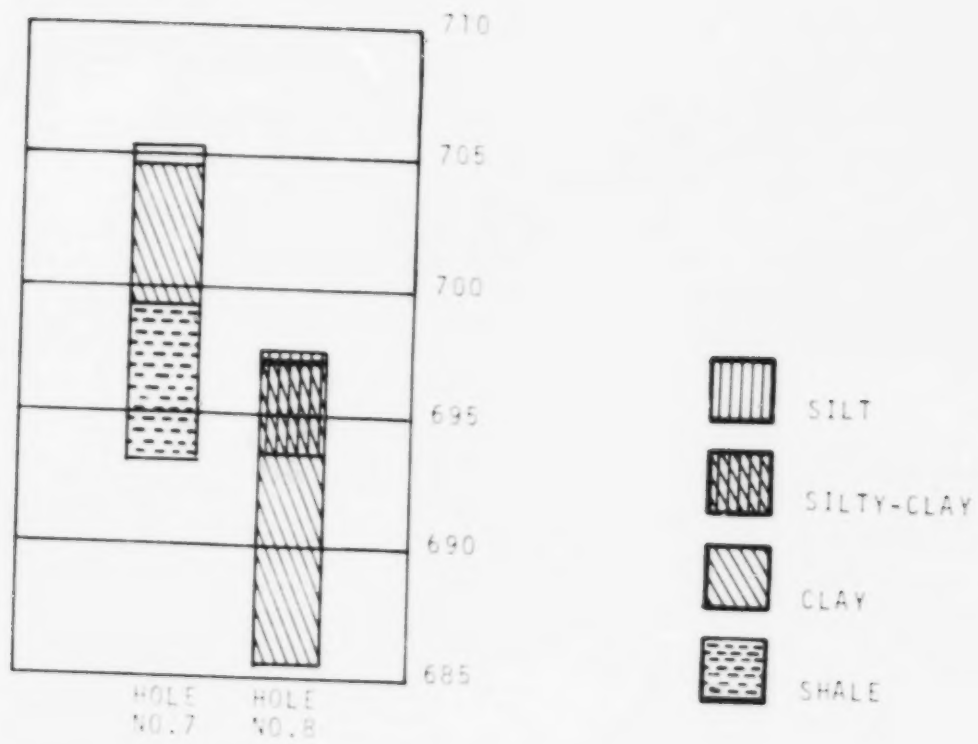
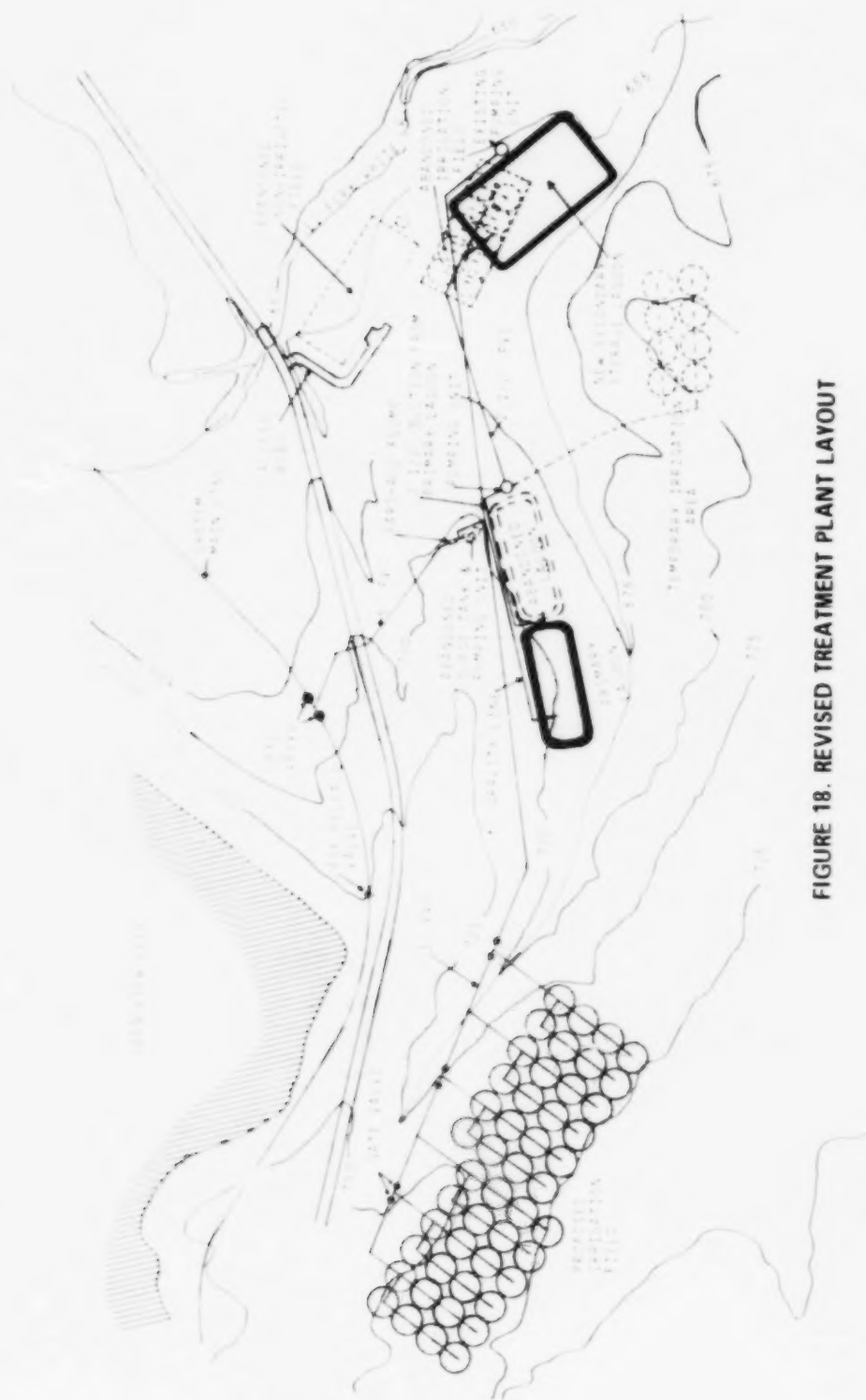


FIGURE 17. LAGOON SITE BORING LOGS



SECTION X

LAGOON EFFLUENT IRRIGATION DATA

As originally proposed, the liquid from the lagoons was to be irrigated onto a hay crop at regular intervals throughout the summer months. A 1-acre irrigation field and similar-sized control field were to be utilized to determine the amount and strength of runoff from irrigated and non-irrigated land. No discharge from the irrigated field was planned other than an amount equal to that from the non-irrigated field. The volume of the discharge was equalized by re-irrigation of any runoff from the irrigated field. A partial failure of the irrigation field crop due to flooding prohibited total operation as originally proposed. Additional irrigation areas were utilized as needed, but conclusions as to the effectiveness of such application in relation to ground slope, type of vegetation, frequency of application were drawn.

Individual applications to the 1-acre field over a 24-hour period ranged from 15,400 gallons to 52,100 gallons or a depth of 0.57 to 1.92 inches. The normal operating level was about 24,000 gallons or 0.88 inch. The period of recovery between applications varied with temperature, humidity and wind velocity.

Total crop irrigation during 1971 was as follows:

<u>Month</u>	<u>Gallons</u>
July	15,200
August	31,600
September	7,500
October	14,260
November	<u>2,700</u>
Total	71,260 gallons

Prior to the failure of the lagoon levee an auxiliary irrigation system was laid out in the woods near the treatment plant. In 1971, 74,800 gallons were pumped onto the vegetation without any runoff to the stream. Therefore, the total volume of lagoon effluent discharged to the land in 1971 was 146,060 gallons.

The irrigation system was then moved in December, 1971 to another location where vegetation was thicker than at the previous location. Further damage to the lagoon levee was prevented by irrigating to this area in addition to the irrigated hay field in 1972. Irrigation figures for 1972 are as follows:

<u>Month</u>	<u>Gallons</u>
August	400,625
September	676,332
October	32,150
Total	1,109,107

As noted earlier, when the new lagoon was designed it was recommended that a larger area (5.5 acres) be used for irrigation to effectively consume the liquid volume entering the plant.

The lezbedeza hay crop initially used was killed off by excess water, but a fescue mixture used the second year was hardier. It was found by the operators that the initial application to vegetation areas far exceeded the average load applicable without runoff to the stream. Multiple applications created washed areas on slopes greater than 4 to 1 and pooling in depressions prevented any new growth. The best area for irrigation was one which had dense grasses and trees less than 15-feet tall.

Ideally, the frequency and intensity of application would have been no greater than 25,000 gallons every third day at the Grandview plant due to soil conditions. By anticipating a rotation of irrigation areas to allow such a schedule, the engineer could minimize runoff. Of course, naturally-wooded areas might utilize a greater or lesser volume of liquid per acre due to type of vegetation, ground slope, soil type, etc. It was the engineer's experience that the capability for irrigating several times the average daily irrigation volume was necessary for disposal due to weather factors. One acre could be used to dispose of 1,920,000 gallons $[24,000 \times 1/3 (30 \text{ days}) \times 8 \text{ months}]$ of liquid under ideal conditions. However, a design factor of 1,303,315 gallons per acre or 48-inches of liquid per year was used in sizing the new irrigation area.

SECTION XI

LABORATORY ANALYSES

During the research period of the Grandview Lake Sewage Project, specific laboratory tests were performed to answer the following:

1. What was the strength of the waste at the home pumping units?
2. What was the strength of the waste entering the plant?
3. How effective was the lagoon treatment?
4. How effective was the irrigation step in reducing the strength of the lagoon effluent?
5. How did the runoff from the irrigated field compare to the runoff from the non-irrigated field?

The procedures followed for testing the sewage samples conformed to Simplified Laboratory Procedures for Wastewater Examination, published by the Water Pollution Control Federation (WPCF Pub. No. 18).

Specific tests conducted on the samples collected were:

1. Biochemical Oxygen Demand (B.O.D.)
2. Suspended Solids
3. Orthophosphates
4. Ammonia-Nitrogen
5. Nitrite-Nitrogen
6. Nitrate-Nitrogen
7. Chemical Oxygen Demand (C.O.D.)

Evaluation of the various samples resulted in the following conclusions:

The strength of the sewage found in the home units varied widely with unit type. The septic tank effluent systems had the lowest concentrations of BOD, COD and suspended solids, but also had the most pronounced odor. A higher strength waste was collected at the various home units than was seen entering the plant. This higher strength was to be expected since no sedimentation (septic tank) was provided prior to the pumping units.

After the levee failure, lack of aeration or recirculation and the reduced storage capacity caused the upper portion of the primary cell to turn septic toward the end of the research period. Excellent treatment was obtained by the overall treatment sequence, as evidenced by the field runoff comparisons, shown in Table 7.

Although the data are limited a number of consistencies are evident. First, the plant influent, being a mixture of grinder-pump and septic tank effluent

TABLE 7
ANALYTICAL SUMMARY

Location	Number of Samples	Composite or Grab	Average Concentration, mg/l				
			BOD	COD	SS	PO ₄	N(1)
<u>ONSITE</u>							
Grinder-Pumps	3	G	360	560	470	31	41
Septic Tank Effluent	4	G	110	190	95	22	44
<u>PLANT INFLUENT</u>	5	4C;1G	216	413	170	40	39
<u>LAGOON 1 EFFLUENT</u>	3	G	128	275	140	32	22
<u>FIELD RUNOFF</u>							
Irrigated	3	G	9	49	8	6	15
Non-Irrigated	3	G	11	59	48	NIL	6

(1) Nitrogen data represent sum of NH₃, NO₂ and NO₃ results, expressed as N.

pump flows, generally has measured pollutant concentrations intermediate between the two sources. Secondly, the lagoon effluent does demonstrate some treatment efficiency when compared to the influent, including some nutrient reduction. Finally, the runoff from the irrigated hay field was of somewhat better quality than the non-irrigated field with respect to BOD, COD and suspended solids. An increase in nutrients appears to exist, but when compared to the plant influent, a significant reduction in nutrients appears to take place during the treatment sequence.

A complete list of analytical results is given in Table 8.

Even the limited scope of the testing on this project confirmed that irrigation of treatment plant effluent was an effective method of disposing of domestic sewage.

TABLE 8
ANALYTICAL DATA
(1972)

Location(1) (#)	Date	Sample Type (CorG)	Parameter Measured (Concentrations in mg/l)						
			BOD ₅	COD	SS	PO ₄	NO ₃ -N	NO ₂ -N	NH ₃ -N
1	10/17	G	690	707	1080	23	7	NIL	70
	10/17	G	180	460	145	32	7	NIL	17
	11/1	G	310	508	175	37	5	NIL	18
2	11/1	G	110	191	95	22	4	NIL	40
3	9/5	G	305	553	268	28	1.5	NIL	16
	9/14	C	185	457	136	39	9	1.0	47
	11/30	C	310	462	264	48	0.2	NIL	45
	12/7	C	100	250	80	32	4	NIL	34
	12/11	C	180	382	102	34	0.3	NIL	39
4	9/5	G	170	337	116	27	4	NIL	19
	10/17	G	95	207	140	28	2	NIL	20
	11/1	G	120	282	165	42	5	NIL	19
5	7/25	G	3	58	11	NIL	-	-	0.7
	10/17	G	9	33	6	2.5	1.8	NIL	0.6
	11/1	G	16	56	6	16	18	NIL	8.0
6	7/25	G	4	62	7	NIL	-	-	0.8
	10/17	G	19	61	60	NIL	1.8	NIL	0.2
	11/1	G	10	44	78	NIL	4	NIL	5.0

Location: 1 - Grinder Pumps
2 - Septic Tank Effluent Pumps
3 - Plant Influent
4 - Lagoon 1 Effluent
5 - Irrigated Field Runoff
6 - Non-Irrigated Field Runoff

SECTION XII

COSTS AND DISCUSSION

One of the anticipated results of the Grandview Lake Research and Demonstration Project was to provide inexpensive sewers to rural areas. It appears that a price of about \$600 to \$1,500 for each individual grinder-pump can be anticipated. The engineer originally felt that a unit could be produced for less than \$500. Since present financing limitations per customer in sparsely populated areas are such that only about one-third of the borrowed monies can realistically be applied to a grinder-pump unit, i.e., two-thirds would be applied to system piping and treatment facilities, this early estimate would have enabled greater application of the pressure sewer approach. There is the possibility that free market conditions may force the price of the grinder-pump units down. This would make future projects more feasible.

It was found that a great amount of engineering time, especially in the field, and close construction inspection was needed during installation and start-up of the system and home units. It is anticipated that as contractors become better acquainted with pressure sewer systems that this would be minimized.

The impact of the sewer system being available to the lot owners was best seen in two indicators; the ratio of permanent residences to part-time residences and the purchase price of lots before and after the pressure sewer installation. When the system operation was begun in November 1970, there were 22 houses that were occupied on a full-time basis and 36 on a part-time basis. By June 13, 1972, the number of part-time occupancies was negligible and 100 permanently-occupied homes were anticipated in the area served by the initial system. During the same period of time the value of the lots had increased as much as 45 percent. The reluctance of potential buyers to locate where sewer facilities were not available was overcome by the pressure sewer system.

The construction cost summary for the pressure main is presented in Table 9. In addition, the treatment facility, including the lift station capital cost was \$32,142. Therefore, the total capital cost per home would be the sum of the pressure main and treatment facility, divided by the number of homes served, added to the cost of the onsite facility of each homeowner. The approximate costs of the various units employed in the study are given in Table 10. Since the number of operating units varied throughout the study and since a number of original units were replaced during the course of the project, an exact average cost is not easily computed. For example, if the original 58 homes were chosen, the average cost of the main and treatment facilities per home was \$1,166, plus the onsite cost. If the ultimate projection of 100 homes were chosen, the average cost drops to \$676, plus the onsite facilities.

TABLE 9
PRESSURE SEWER COST BREAKDOWN

<u>Item</u>	<u>Quantity</u>	<u>Unit Cost</u>	<u>Total</u>
5-inch PVC (SDR 26)	635 ft	\$2.00/ft	\$ 1,270
3.5-inch PVC (SDR 26)	11,475 ft	1.10	12,622
3-inch PVC (SDR 26)	14,155 ft	1.10	15,571
2-inch PVC (SDR 26)	1,230 ft	0.90	1,107
Blacktop Road Repair	40 ft	3.00	120
Manual Air Release Valves	6	125.00 ea.	750
Automatic Air Release Valves	4	200.00	800
Mainline Gate Valves & Boxes	2	100.00	200
Total Cost*			\$32,440

*Bid cost, not including \$1,000 vacuum collection station.

Actual cost, including vacuum station, was \$33,044.

Final cost including additional items such as an extension of the main, line relocation, county blacktopping and rock excavation was \$35,491.

TABLE 10

APPROXIMATE HOME UNIT COST COMPARISONS

Type of Unit	Delivered Cost (1)	Installation Cost	Service Line & Connection Cost (2)	Total Cost
Septic Tank Effluent Pump and Tank (3)	670	200	160	1030
Hydromatic GP	920	200	160	1280
Environment One GP	950	200	160	1310
Falsa GP	600	200	160	960
Moyno GP	600	200	160	960
Flushing Unit with 1000 gallon Tank	750	450	200 (4)	1400

- (1) Cost includes equipment, assembly (if required), and all ancillary items for complete system, excluding electrical hookup.
- (2) Installation of approximately 180 ft. of 1-inch PVC service line, curb cock, and all other service line needs.
- (3) When new installation, approximately \$400 must be added for septic tank.
- (4) Larger (1.5-inch) service lines generally required for flushing units.

Due to the experimental nature of the project, an unusual amount of public relation work had to be done on the Grandview project. The engineer was very fortunate to have a Utility Board composed of engineers and businessmen familiar with research and development projects. They understood that everything was not going to function perfectly from the start. They did an excellent job of explaining to the homeowners that problems would arise, but that they would be dealt with as soon as possible. Generally, the attitude of the homeowners was very good. They realized that the "bugs" had to be worked out of the system and there would be some inconveniences. The alternative to the project, septic systems leaking into yards and the lake, no doubt was an influencing factor in their attitude.

The initial concept of the engineer was to develop a fractional horsepower grinder-pump unit with parts that were readily available to the homeowner in the event of malfunction. The horsepower was to be kept to a minimum to help reduce the homeowner's electrical bill. It became very evident during the project that the homeowner was neither interested in a low electric bill nor able to service the unit himself. He simply wanted a maintenance-free sewer system.

The community's primary goal was to obtain a functional sewer system. The research project funds provided a start toward that goal, but were never intended to be limited to that use. Knowledge was gained from the failures as well as the successful parts of the project.

SECTION XIII

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4. Hendricks, G. F., "Pressure Sewer System and Treatment at Grandview Lake, Indiana," Proceedings of Ohio Home Sewage Disposal Conference, Columbus, Ohio, January 29-31, 1973.
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SECTION XV

GLOSSARY

<u>English units</u> ()	$\times$	<u>Conversion factor</u> ()	$=$	<u>Metric</u> ()
<u>Length</u>				
mile		1,609		kilometer
foot		0.305		meter
inch (")		25.4		millimeter
<u>Area</u>				
acre		0.404		hectare
<u>Volume</u>				
gallon		3.786		liter
<u>Mass</u>				
pound		0.454		kilogram
<u>Volume rate of flow</u>				
gallon/day (GPD)		0.0038		meter ³ /day
gallon/minute (GPM)		0.0631		liter/second
<u>Volume loading rate</u>				
gallon/acre		0.0094		meter ³ /hectare
<u>Pressure</u>				
pound(lf)/square inch(ksi)		6.895		kilopascal
<u>Power</u>				
horsepower		0.7457		kilowatt